Sky and TELESCOPE

In This Issue

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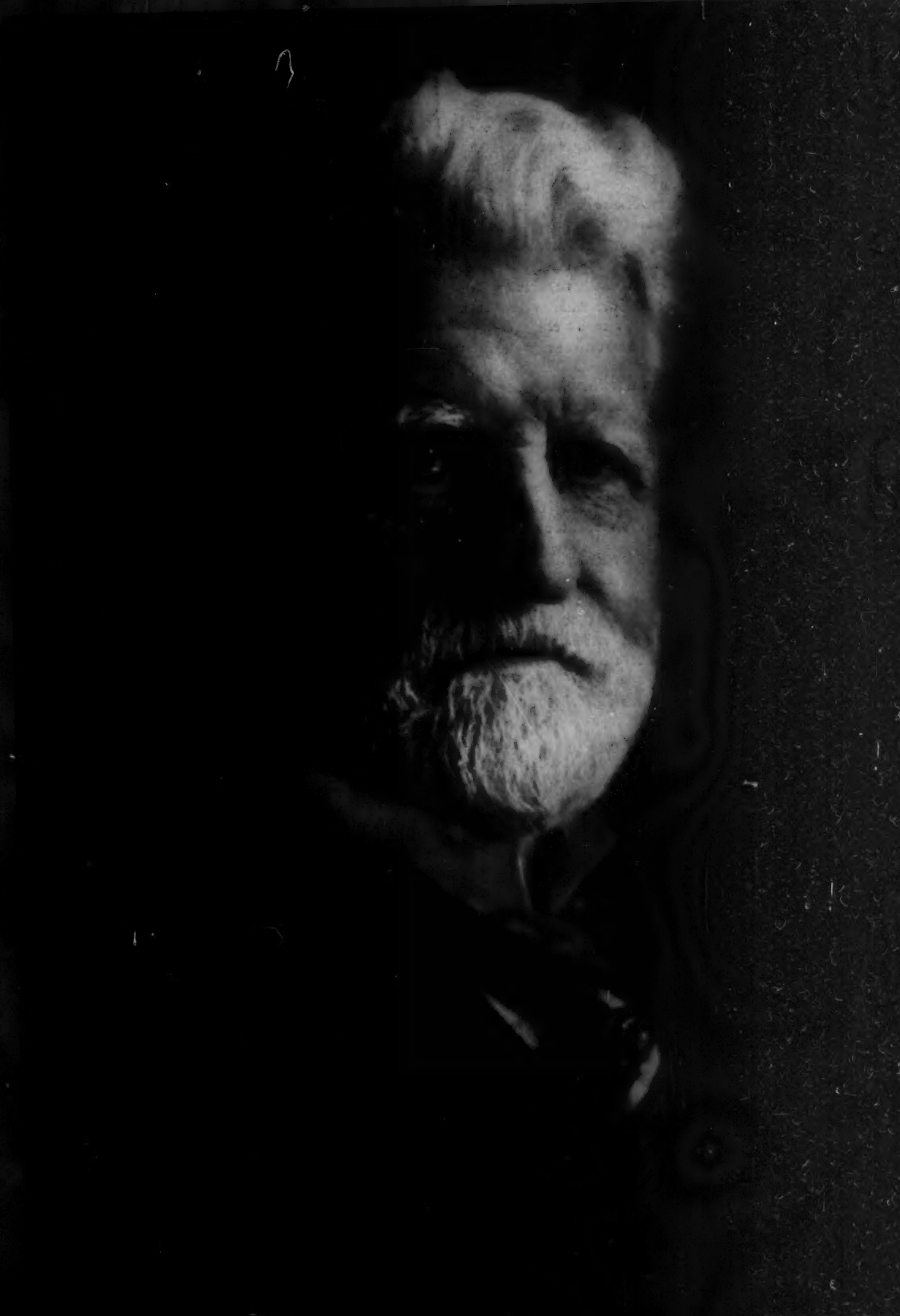

Ambrose Swasey
(1846-1937)

The Editors Note . . .

A news note worthy of special attention by all of our readers.

THE American Astronomical Society's Committee on the Continued Distribution of Astronomical Literature has just received a packet of various German astronomical journals and publications from seven German observatories, issued in 1939-41 and the first half of 1942. The stack, fully eight inches deep, is truly impressive, not only in bulk but in its evidence for continued serious research. Practically every branch of astronomy is represented, from historic researches on Mayan astronomy, observations of asteroids, meteors, and variable stars, to highly technical work in celestial mechanics, various astrophysical problems, stellar statistics, and so on. Solar research, studies of Cepheid variables and of the zodiacal light are especially prominent.

The annual reports of directors of observatories give clues as to the effect of the war on the astronomers themselves. As in the case of our own observatories, the Germans have had to sacrifice some of their promising younger men, a few of whom have, indeed, been reported killed in action. A number of other deaths, especially among the older men, are likewise reported. A remarkable percentage of the smaller institutions seem to have suffered changes in directorship, reflecting the restlessness of the times. Among the authors of the papers, we note many unfamiliar or new names. On the whole, we feel far more impressed by an apparent undying interest in astronomy than by a fatalistic resignation to complete militarism among German astronomers. There is even evidence that some who are occupied in war activities find time for volunteer work at their observatories.

Numerous issues give abstracts of astronomical papers published in Italy; one, a list of those published in Japan. Pleasing, however, was the discovery that the numbers of the *Beobachtungs Zirkulär* published in 1942 give the indices of our American *Astrophysical Journal* and *Astronomical Journal*, and of the British *Monthly Notices* and *Observatory*. This indicates the efficaciousness in alien territory of the efforts of the Committee.

We also note the election, since the war began, of a Parisian and a Chinese to membership in the Astronomische Gesellschaft; and that an asteroid, discovered by a German, was named in honor of a Frenchman.

These publications are entirely devoted to astronomy. Their only reference to the war is in the personnel notes in the directors' reports. They serve no propaganda purposes. At almost every meeting of the International Astronomical Union, it has been commented that there are no national barriers among astronomers. We experience the same feeling on reading this mass of German astronomical literature. May our common understanding in this science eventually be extended to life in general.

DORRIT HOFFLEIT

Sky and TELESCOPE

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CHARLES A. FEDERER, JR., *Editor* HELEN S. FEDERER, *Managing Editor*

In Focus

PICTURED on the back cover this month is a striking Lick Observatory photograph of the naked-eye spiral galaxy in Andromeda, which shines nearly overhead these February evenings. This great system of stars rivals our own Milky Way galaxy in size and interest, and is a part of the local group of galaxies, of which there are probably a dozen members.

Although its central plane is inclined only 15 degrees to our line of sight, the galaxy's spiral structure, both close to the nucleus and in the fainter arms, is clearly revealed in this picture. At a considerable distance from the main portions of the system, faint extensions may be traced. Recent studies show these to reach to at least double the diameter of the main parts, giving M31 a total diameter on the order of 100,000 light-years, nearly that of the Milky Way.

The star with the conspicuous diffraction ring and pattern is in our own system, and not part of M31. Just above this star appears the small, but bright, M32, which is a nearly round elliptical nebula, while in the upper right is N.G.C. 205, a peculiar type of elliptical galaxy. We do not know whether these satellites of M31 lie in its plane; if they do, M32 is about 12,000 light-years from the center of M31, and N.G.C. 205 is about 7,500 light-years away.

The outer portions of the Andromeda nebula have been resolved into stars, but not its nucleus. M31 contains numerous Cepheid variables, a few open clusters, and half again as many globular clusters as we can observe in the Milky Way galaxy itself. Novae are frequent—as many as 25 or 30 per year, and one supernova was recorded in 1885. It is evident that in some respects we have a better view of this exterior galaxy than of our own!

The total brightness of M31 is on the order of two billion times that of the sun; its mass is perhaps 10 billion suns. It appears to be coming toward us (or we toward it) at about 130 miles per second; neither it nor other members of the local group display the red shifts characteristic of the "expanding universe."

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COVER: Ambrose Swasey (1846-1937), co-founder with W. R. Warner of the Warner and Swasey Company, Cleveland, Ohio. Photo by Harris & Ewing.

BACK COVER: The Great Nebula in Andromeda, M33, and its companions, M32 (*lower center*) and N.G.C. 205 (*upper right*), photographed with the Crossley 36-inch reflector (focal length, 209 inches) at Lick Observatory by Nicholas U. Mayall. The exposure time was 4½ hours, on November 7, 1937. The center of the nebula was locally reduced to bring out the intricate spiral structure, at the same time preserving the faint outer portions of the spiral. The enlargement is about 1.8 times the original negative, on which the scale is about 37 seconds of arc per millimeter.

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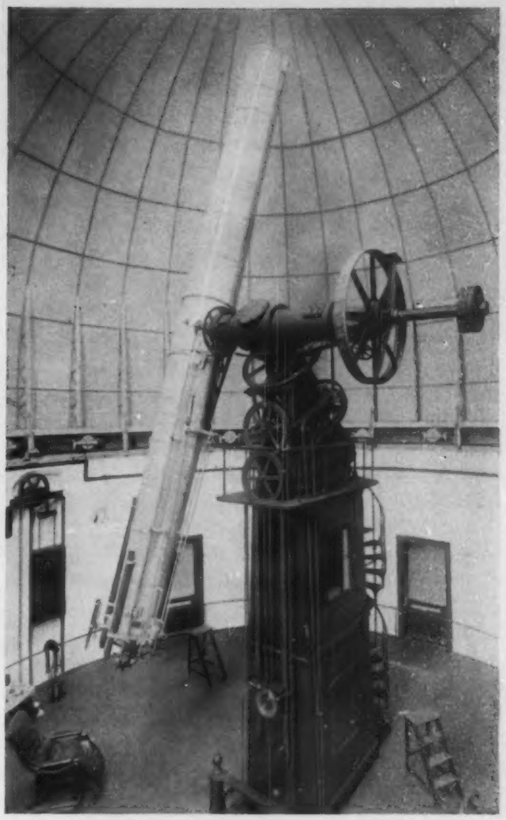
Ambrose Swasey
Telescope Engineer

By Ralph S. Bates

Massachusetts Institute of Technology



Warner and Swasey rebuilt the mounting and dome of the 26-inch refracting telescope at the United States Naval Observatory, pictured here. It was with this telescope, the largest in the world when it was built, that Asaph Hall discovered the satellites of Mars in 1877.

AMBROSE SWASEY, were he still living, might well complain that the title of this article failed to do him justice. He was inventor, manufacturer, traveler, philanthropist, scholar, promoter of religious education, creator of an engineering foundation, and many other things as well. But while others have endowed churches, schools, societies, and museums even more lavishly than Swasey was able to do, his long career as a donor of astronomical instruments stands unique in the annals of American philanthropy.

Ambrose Swasey, the son of Nathaniel and Abigail Chesley Peavey Swasey, was born in Exeter, N. H., December 19, 1846. Like most men who achieve renown in science, he showed an aptitude for mechanical construction while he was still a boy; he had a shop in his attic where he did lathe work. At the age of 18 he started upon a three-year apprenticeship in the newly established Exeter Machine Works. It was here that he later met the man destined to be his business associate for over 60 years, Worcester Reed Warner. In 1869, these two entered the employ of Pratt and Whitney Company, of Hartford, Conn.

Swasey received his first patent in 1875 for the invention of a protractor for measuring angles with extreme accuracy. In 1878, he was made superintendent of the gear-cutting department of Pratt and Whitney. The following year saw his construction of an epicycloidal milling machine. In the latter year, too, he received and declined an offer to become instructor in mechanical arts at Cornell University.

After 11 years with Pratt and Whitney, the two men set up independently in Chicago a machine tool business under the name of Warner and Swasey. The following year the firm moved to Cleveland. While the turret lathe was the principal product of the company, all sorts of milling and metal working machines were furnished as the business expanded and came to include branches and agencies in over a dozen foreign countries.

Since both Warner and Swasey were interested in astronomy, they applied their engineering skill to the construction of telescopes. Their first real instrument was a 9½-inch equatorially mounted refracting telescope, which went to Beloit College in Wisconsin. In 1882, a revolving dome, 45 feet in diameter, was constructed for the 26-inch telescope of the Leander McCormick Observatory of the University of Virginia.

In 1874, James Lick gave the trustees of the University of California $700,000 "to provide for the construction of a telescope larger and more powerful than any in existence, and a suitable observatory connected therewith." A 36-inch lens, secured from Feil and Son, of Paris, was figured and polished in the shop of Alvan Clark and Sons, of Cambridge, Mass. Although its bid was the highest of all submitted, the firm of Warner and Swasey secured the contract for making the mechanical mounting for the telescope, and in 1888, the James Lick telescope was erected on Mt. Hamilton, in California, 50 miles south of San Francisco. It is amusing to learn that even the best of telescope men make mistakes now and then. When the 36-inch objective was mounted in the tube, Alvan Clark, Jr., was much perturbed to discover that the focal length was six inches less than specified in the order, but Swasey proceeded to relieve his anxiety by cutting six inches off the lower end of the tube with a hack saw.

The performance of the Lick telescope was so satisfactory that, in 1893, the United States government commissioned Warner and Swasey to make a new mounting for the 26-inch at the Naval Observatory, and to equip the observatory with an elevating floor and a new dome.

The partners next designed the mechanical parts of the world's largest refracting telescope, the 40-inch Yerkes instrument, located at Williams Bay, on Lake Geneva, Wis. The telescope mounting was exhibited at the World's Columbian Exposition in Chicago in 1893, and three years later was mounted in the observatory. The Clarks figured the lens. Warner and Swasey built the revolving dome, 90 feet in diameter, and the floor, 75 feet in diameter, with a rise and fall of 25 feet. In the design and construction of these pieces of equipment, massive steel structures delicately balanced and readily controlled, Swasey is given high credit for his sense of symmetry and proportion.

With the coming of the 20th century, the firm of Warner and Swasey turned to the construction of reflecting telescopes. Their first large job of this character was the mounting, dome, and observing bridge of the telescope at the Dominion Astrophysical Observatory, near Victoria, B. C. The optical parts for this instrument were furnished by the John A. Brashear Company, Ltd., of Pittsburgh. Of this telescope, the late Dr. J. S. Plaskett, director of the observatory, wrote:

"The beautiful lines of this mounting, unequaled in either earlier or later telescopes, were due to the engineering artistry of Mr. Swasey, who possessed a real genius in harmonizing the mechanical design with the beautiful and satisfying in appearance. This telescope set a new standard in accuracy, convenience and speed of operation, amply confirmed by the quality and quantity of the work produced in its twenty years of operation."

A mounting and dome for the 60-inch reflecting telescope for the Argentine National Observatory at Cordoba were finished in 1922 (see *Sky and Telescope*, March, 1942). A 69-inch reflector and

dome were made in 1923 for the Perkins Observatory of Ohio Wesleyan University. J. W. Fecker, successor to Brashear, furnished the optical parts for both these instruments. The death of Swasey on June 15, 1937, occurred just as Warner and Swasey were completing the 82-inch reflector for the McDonald Observatory of the University of Texas, on Mt. Locke, near Fort Davis, Tex.

Swasey himself considered his greatest achievement in the design of precision mechanisms to be a dividing engine for graduating circles which he completed in 1898. This machine was capable of graduating a circle 40 inches in diameter without making an error greater than 1/12,000 of an inch; or, to put it another way, if the circle were enlarged to a diameter of six miles, no graduation would be out of its correct position by as much as an inch.

In World War I, Swasey designed and built the Swasey depression finder and an azimuth instrument for coastal defense. For his skill in the construction of these and other instruments, he won high praise from Army officials, including the Chief of Ordnance. The firm of Warner and Swasey also built quantities of telescopic musket sights, naval gun sights, and panoramic sights.

The many philanthropic gifts which Mr. Swasey made during his lifetime must have totalled over a million dollars; although most of them lie outside the scope of this article, a few may be mentioned. In 1916, he presented a Science Building to the University of Nanking, China, and in company with Brashear, he attended the dedication exercises. On the way he visited the Chinese Observatory on the Inner Wall of Peking, and later took an active part in securing the return, under the provisions of the Treaty of Versailles, of some old 17th-century French instruments which the Germans had removed to the Potsdam palace at the time of the Boxer rebellion.

This 9½-inch refractor stood for 25 years between the residences of Warner and Swasey. It is now a part of the observatory named after these men.

In 1899, Swasey and his partner presented a 10½-inch refracting telescope to Western Reserve University. In 1910, Swasey gave Denison University a beautiful astronomical observatory, equipped with a 9-inch refractor and a 4-inch zenith telescope. The Warner and Swasey Observatory of the Case School of Applied Science in Cleveland acquired a 9½-inch refractor, dedicated in 1920, which had stood for 25 years between the residences of Warner and Swasey. At the Paris Exposition in 1900, it had been the only instrument to receive a gold medal. At the ceremony of dedication, Swasey observed:

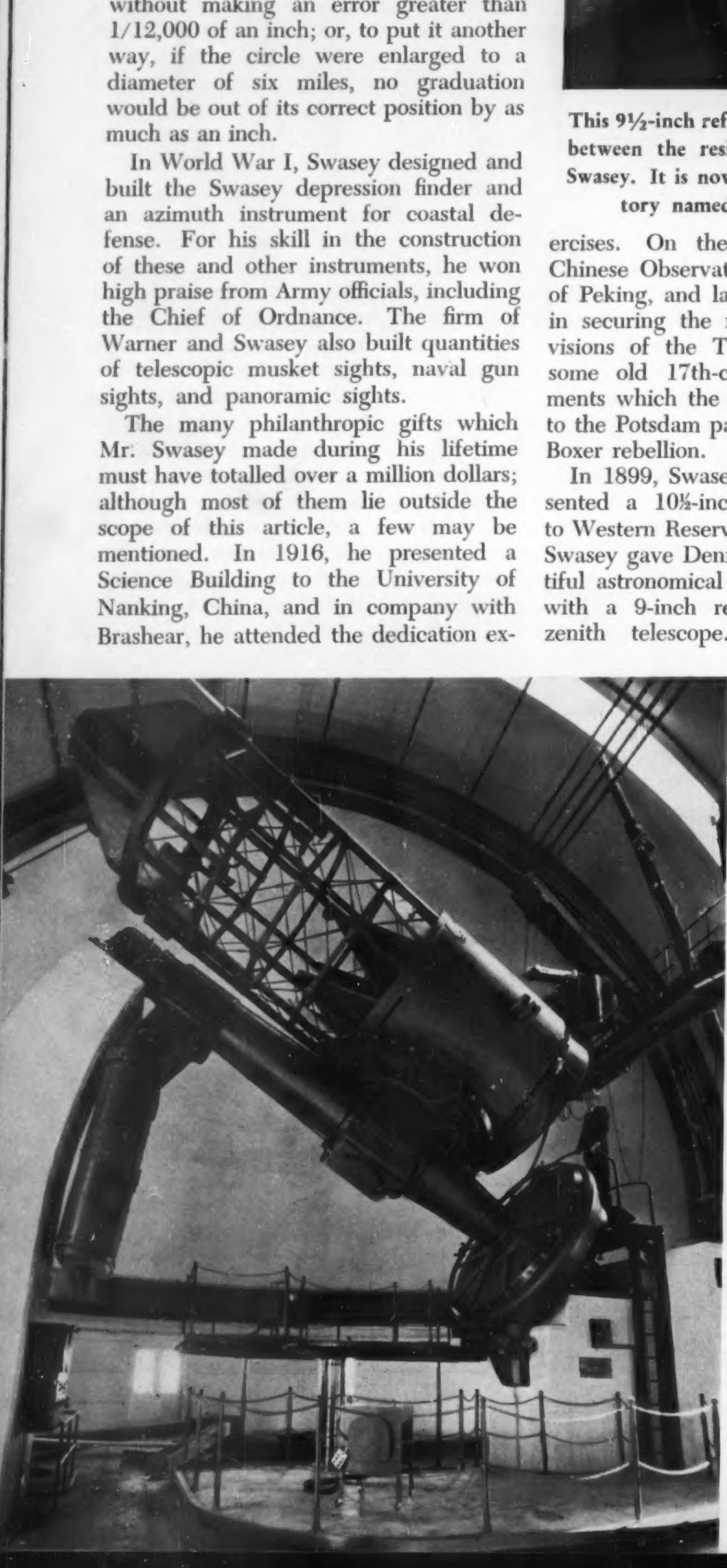
"Mr. Warner and I are often asked if building telescopes is our only business and sometimes I have answered that we get our money out of machinery and our glory out of telescopes. However, while the monetary reward may have been meager, we have been amply compensated for all our astronomical work by the benefits we have received from the men of science with whom we have been associated at this work."

It was highly fitting that his heirs contributed generously toward the expansion of the Warner and Swasey Observatory, which was completed in 1941 and equipped with a Schmidt-type telescope (*Sky and Telescope*, February, 1942).

The United Engineering Societies conferred the John Fritz medal upon Swasey for his achievement "as a designer and manufacturer of instruments and machines of precision, a builder of great telescopes . . . ." He was awarded the Hoover gold medal by the American Society of Mechanical Engineers in 1936. Seven universities conferred honorary doctorates upon him: Case, Denison, Brown, the Universities of Pennsylvania, California, Rochester, New Hampshire. Asteroid 922, discovered by Otto Struve at Yerkes, was named Swaseya in his honor.

Swasey was a member of the National Academy of Sciences, and numerous engineering and scientific societies, including the American Astronomical Society, the British Astronomical Association, and the Royal Astronomical Society. He was one of the founders of the American Society of Mechanical Engineers, and its president in 1904. In 1914, he gave an initial and anonymous gift of $200,000 to establish the Engineering Foundation, and later gifts brought the total of his munificence to that establishment up to $839,000. He participated in the formation of the National Research Council in 1916, and served for years on its division of Engineering and Industrial Research.

Ambrose Swasey died of pneumonia at his ancestral home, Fort Rock Farm, in Exeter, N. H., on June 15, 1937, aged 90 years, five months. This devout man, who was fond of quoting from the Psalmist, "The Heavens declare the glory of God and the firmament sheweth his handiwork," was interred in Exeter cemetery. But the real memorials to Swasey and his partner Warner are not domes of marble, but rather the domes of steel in the many observatories which they built.



The 82-inch reflecting telescope of McDonald Observatory on Mt. Locke, Tex., was dedicated in May, 1938, less than a year after the death of Ambrose Swasey. This telescope has the most modern equipment, with which many important astronomical discoveries have been made.

THE 69TH MEETING OF THE A. A. S.

BY OLIVER J. LEE, *Director, Dearborn Observatory*

AT the dinner meeting of the Council of the society the pretty brunette waitress looked at our treasurer, Dr. Keivin Burns, who was the last to order his dessert, and remarked, "You look as if you might want apple pie." He replied, "Yes, I'll take apple pie."

If law and order connotes adherence to decisions and actions of the majority, this meeting was lawless. Our officers and Council, most of whom were parties to loading the nation's transportation facilities with tens of thousands of college students bent on vacations to their homes or elsewhere, felt that perhaps there was no logical reason why we should not gather, even if most of the larger learned groups called off their holiday sessions. The meeting was a small one in numbers. It reminded some of us of the small, intimate groups which convened before and during the first World War.

The symposium on Science Courses in the War Effort seemed to us a valid positive reason for holding our meeting. After it was over, those of us who were present still think so.

As usual, the papers which were read by authors, proxies, or by title, covered much territory. Observational material with or without generalization or interpretation and theoretical papers vied with each other for attention. Inasmuch as abstracts of most of the papers will be published before very long, it seems almost unfair, or at least indelicate, to single out one or a few for mention in this brief report.

The society is deeply indebted to Dr. Newton L. Pierce, of Princeton, and to Comdr. Smith D. A. Cobb, U.S.N., and Prof. Everett Edmondson, of Northwestern, for a most realistic and informative combat of ideas about pre-induction teaching of navigation.

Dr. Pierce outlined the content of courses being given to Princeton students in preparation for duty in the Navy and Air Corps.

"If you want to help us train officers," commented Comdr. Cobb, "you will teach only the basic parts of celestial navigation. If you want to hinder us, you will tell your students you are teaching them navigation. The man who realizes he doesn't know much about the subject can be taught, but the man who thinks he has mastered the subject is worthless." Speaking as an individual of much experience with the sea, and not for the Navy, he added, "Navigation is the most misused word in the English language. The only way to learn navigation is to navigate."

Dr. Pierce spoke of teaching the use of modern tables such as H.O. 214 and 218. Comdr. Cobb countered by saying that not nearly enough copies could be had, especially for the younger officers, who often do not have access to the books and instruments of their superiors. Therefore they must understand the basic principles thoroughly in order to navigate. He urged that compass correction be taught, concentrating especially upon making deviation cards, but not attempting to teach compensation of the magnetic compass.

Dr. Edmondson deprecated the use of the Mercator projection charts in air navigation and expressed his decided preference for Lambert conformal conic projection charts, based upon his experience in flying over a million miles as a pilot in the Army Air Corps and commercially.

Dr. Pierce and the writer emphasized that familiarity with the positions and apparent motions of the sun, the moon, stars, and even planets, is of tremendous value to men in the Services on land as well as on the sea and in the air. With this knowledge acquired from intelligent observations of the heavens on every clear night, men can often save lives and property without computation tables or instruments of navigation. This comes from the fact that the vast majority of military operations will, in the future, involve relatively short distances, in which latitude and longitude are of less importance than are approximate azimuths or bearings, gotten by a glance at the moon, the sun, Polaris or other known bright star. Comdr. Cobb and Dr. Edmondson agreed about the value of such instruction for cadets.

The locked-horns discussion brought out the age-long contrasts between the men who teach and the men who do, and, that there is no substitute for experience.

It seems that if we who teach take full advantage of the opportunities to instruct our students in the simple yet fundamental elements of naked-eye astronomy and are modest in naming our pre-induction courses, we shall probably do most for our students and for the war effort.

To be again assembled under the inimitably rich, mellow, and humorous chairmanship of President Stebbins was an experience the rest of us shall long treasure.

Members and guests at the 69th meeting of the American Astronomical Society, Dearborn Observatory, December 28-30, 1942. Abstracts of some of the papers given will appear in the March issue of this magazine. The regular technical abstracts will be published in the "Astronomical Journal."

Computing the Position

H. O. 208 and 211

In January, Dr. Fred L. Whipple explained the use of the Nautical Almanac in celestial navigation. Here, the editors continue the problem of finding a fix for the good ship Namedeleted, *somewhere in the Atlantic.*

LAST month, in "The Use of the Nautical Almanac in Practical Navigation," were discussed the various data which a navigator must extract from his *Almanac* as the first part of working a celestial sight to obtain a line of position at sea. Here, using the same observations, we shall derive the two quantities, computed altitude and azimuth, for the sun sight using the method of Dreisonstok (Hydrographic Office Publication 208), and for the moon sight using the method of Ageton (H.O. 211). It is in this portion of our problem that all short-cut methods seek to save time, some at the expense of accuracy, others by providing cumbersome tables or equipment. Ageton and Dreisonstok are small pocket volumes, self-sufficient, and probably more widely taught than any other methods. Ageton costs but 90 cents, while Dreisonstok is $1.20, so the use of either can be recommended to amateur astronomers and navigators who wish to become acquainted with modern methods of navigating. Inasmuch as possession of the publication itself is essential to actually working a sight, our purpose here is to show the simplicity of the methods, and to prepare our readers for the final plotting of lines of position.

In common use today on the larger vessels and airplanes is H.O. 214, a remarkable result of Works Projects Administration labor. It is composed of rather large volumes, each covering 10 degrees of latitude. For aviation use, a more compact form has been produced in H.O. 218. Instructors, however, usually include Ageton or Dreisonstok in navigation courses, in order that the student may become independent and carry his navigation tools "in his pocket."

Ageton and Dreisonstok are essentially simplifications of the old cosine-haversine methods of solving the astronomical triangle (see *Sky and Telescope*, September, 1942), in fact, Ageton is merely a table of the logarithms of secants and cosecants of angles. Dreisonstok, on the other hand, is a combination of several logarithms in two tables, but it can be used with the same ease as Ageton. Pre-arranged forms, such as those shown here, make omissions almost impossible, but, of course, one must guard carefully against arithmetical errors.

The work forms completed last month provide us with a corrected h_o (observed altitude), the Greenwich hour angle for the observed body at the instant of observation, and the declination for the same instant. In this month's forms are also shown the *DR* position, the watch time, and the date.

Fundamental in using Dreisonstok is the assumption of a longitude such that when it is applied to the *GHA*, the resulting *LHA* is in even degrees. In our problem, since we are west of Greenwich, the *LHA* of each body must be less than the *GHA* by the amount of the longitude. Reference to the sun form will show how the *LHA* is made an even 79°. A latitude to an even number of degrees is also assumed, in this case, 42° N. Plotting from the assumed position will give us the same lines of position as we would get from an Ageton solution, which is worked directly from the dead-reckoning position.

In both cases, we go into (enter) our tables with *t*, the meridian angle of the body. This and local hour angle describe the same thing, but *LHA* is always measured from the meridian westward through 360°, whereas *t* is measured *east or west to 180°, and must be labeled E or W*. In the sun sight, *t* has the same value as *LHA*, because the sun is west of the meridian, but in the case of the moon, which is east of the meridian, *t* is equal to 360° minus the *LHA*.

Briefly, the procedure with Dreisonstok is: Using latitude 42° and meridian angle 79° to enter Table I, we write simultaneously from one line therein the values of b, A, C, and Z′. Combining the declination, d, with b, we enter Table II with the value of d+b, and interpolate for B and D. After adding A and B, and C and D, we look in the columns of Table II for these same or interpolated values. A+B gives h_c, and C+D gives Z″, which is combined with Z′ according to rules given with the tables.

The azimuth, Z, obtained in both Ageton and Dreisonstok, is always labeled with two letters; the first is the same as that of the latitude, the second, the same as *t*. It is customary, however, to express azimuth in navigation by measuring eastward from the north point through 360°. Z_n shows this corrected azimuth in each case.

Thus, we have already found a computed altitude and azimuth. There remains for us to take the difference of observed and computed altitudes to give us the *intercept* (*o—c*), and on the last line of the Dreisonstok form is shown the data required to make our plot from the assumed position. Whether the intercept is to be plotted toward or away from the observed body may readily be remembered from Computed Greater Away, the initials being those of the Coast Guard Academy.

TABLE I

L° \ t°	281° b		79° A	C	Z′	280° b		80° A	C	Z′	t° / L°
	°	′			°	°	′			°	
0	90	0.0	71940	8	90.0	90	0.0	76033	7	90.0	0
1	84	46.4	71765	8	84.9	84	15.6	75819	7	84.3	1
2	79	37.7	71250	8	79.8	78	37.8	75196	7	78.8	2
3	74	38.5	70421	9	74.9	73	12.4	74197	7	73.5	3
—	—		—	—	—	—		—	—	—	—
40	12	48.7	18099	124	16.8	11	41.5	18283	122	15.3	40
41	12	22.8	17284	130	16.5	11	17.8	17456	129	15.0	41
42	11	57.9	16495	137	16.2	10	54.9	16655	136	14.8	42
43	11	33.8	15731	144	15.9	10	32.9	15882	143	14.5	43
44	11	10.6	14990	151	15.6	10	11.6	15131	150	14.2	44

TABLE II—*d+b*

	30° h_c 30°	Z″ 59°	31° h_c 31°	Z″ 58°	Corr. Z″	
′	22 B	D	21 B	D	°	′
0	30103	239	28816	221	1.0	60
1	30081	238	28795	221	1.0	59
2	30059	238	28774	221	1.0	58
3	30037	238	28753	220	1.0	57
15	29776	234	28502	217	.8	45
16	29755	234	28481	217	.7	44
17	29733	234	28461	216	.7	43
18	29712	233	28440	216	.7	42
19	29690	233	28419	216	.7	41

AGETON

′	30° 00′ A	B	30° 30′ A	B
0	30103	6247	29453	6468
	30092	6251	29442	6472
1	30081	6254	29432	6475
	30070	6258	29421	6479
2	30059	6262	29410	6483
	30048	6265	29399	6487
3	30037	6269	29389	6490
9	29907	6313	29261	6535
	29896	6316	29250	6539
10	29885	6320	29239	6543
	29874	6324	29229	6546
11	29863	6328	29218	6550
	29852	6331	29207	6554

Portions of Dreisonstok and Ageton, showing some of the data used in our problem.

The procedure with Ageton is abbreviated as follows: Ageton is but one set of tables, and all values are obtained using degrees and minutes as arguments, or entering the table with an A or B value to extract the corresponding B or A value, or a value in degrees and minutes. No interpolation is necessary, so we may work to the nearest half minute, and to the nearest A or B value. To start, we use *t* and *d*; later, we use *L* from the dead-reckoning position. In this case, *t* gives an A value of 29885, and *d* gives B as 636 and A as 76975, shown in their proper places in the form. All operations are additions, except

(Continued on page 19)

FORM FOR DREISONSTOK -- H.O. 208

G.H.A 144° 23.′9	*Dec.(d)* 18° 19.′9N	*Body Obs:* Sun L limb	h_o 20° 26.′4
Ass. Long. 65° 23.′9W	*L.H.A.* 79.°0	*DR Lat.* 42° 08′N	*Date* 5-13-43
t* 79° W	d 18° 19.′9N	*DR Long.* 65° 32′W	*W* 17-34-26
*Ass. Lat.** 42° N	b 11° 57.′9N	A 16495 C 137	Z′ 16.°2
	d+b 30° 17.8	B 29716 D 233	
h_c 20° 11.′1	← A+B 46211	C+D 370	Z″ 66.°9
h_o 20° 26.′4			Z N 83.°1 W
PLOT: (o-c) +15.′3	*(+ is toward)* Z_n 276.°9	*from Long.* 65°23.′9W	*Lat.* 42° N

In using the Dreisonstok form at the left, several rules given in the tables themselves must be adhered to.

Saturn, the ringed planet.

Mars, the ruddy wanderer.

Jupiter, the giant.

OUR PLANETARY NEIGHBORS

BY WILLIAM H. BARTON, JR.

Not even in Nature itself are the motions of the planets so dramatically portrayed as in a modern planetarium. The Hayden Planetarium's story this month is told here.

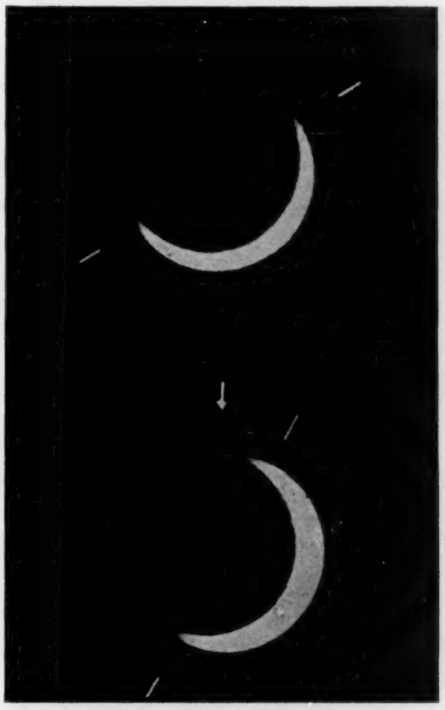
THIS year marks the 400th anniversary of the Copernican system of astronomy. Up to 1543, and for a long while afterward, the Ptolemaic system was the basis of astronomical thought. From time to time, several other systems have been proposed, but generally we think of only two, the one of Ptolemy, the other of Copernicus.

In May, four centuries ago, the first copy of an epoch-making book was placed in the hands of its author while he lay dying. But by no means were the new astronomical theories of Nikolaus Kopernicki, a Polish monk, adopted immediately upon their appearance in his *De Revolutionibus Orbium Caelestium*. Even several hundred years later, the two systems of thought were taught as alternative ideas. There was still no proof that the earth was moving around the sun, but it came in due course.

The early Greek philosophers attempted to explain the apparent motions of the heavenly bodies by assuming the earth to be a fixed center around which the various planets spun. As early as the 3rd century B.C., Aristarchus of Samos proposed that the earth and the other planets went around the sun, but Apollonius, Hipparchus, and Ptolemy supported the fixed-earth notion. They did it so convincingly that for 14 centuries the planets were believed to circle the earth in *deferents* and *epicycles*. On the outside of the universe was the *primum mobile*, which furnished the power to keep the "planetarium" going.

It is true that the "wandering stars" displayed motions that were very difficult to explain, even though in those days there were only seven such bodies known. These were the sun, the moon, Mercury, Venus, Mars, Jupiter, and Saturn. The moon traveled eastward among the stars at such a speed that in a month—a *moonth*—it circled the sky. The sun did the same, but it took a year to complete its circuit, and its motion was more difficult to observe—in fact, it could be inferred only by the change in the stars seen at night.

Mercury and Venus were never very far from the sun, and sometimes they went eastward, sometimes westward, popping out on the eastern or western side of the sun, alternately becoming evening and morning stars. Each was not always recognized as the same body when it had made the transfer. Mars, Jupiter, and Saturn moved more slowly, generally eastward, but once each year the latter two went westward for a spell. Mars did likewise at less frequent intervals, but with much greater variation of apparent speed and brightness.



Venus, the brightest planet, has an atmosphere which transmits sunlight, as shown by the extensions of the crescent at inferior conjunction. These photos were taken in broad daylight.

What could the ancients make of all this confusion? Only a rather cumbersome and confusing picture until Copernicus at last convinced many scientists that the true place for the earth was among the planets circling the sun, not at the center of the universe. From this *moving* point of view, the backward motions of Mars, Jupiter, and Saturn, their variations in brightness and speed, were easily explained. In each case, our own motion was being added to or subtracted from that of the planet.

A half century after Copernicus, the great Johannes Kepler developed the laws that describe the motions of the planets around the sun. From one of these we learn that the farther a planet is from the sun, the more slowly it moves in its orbit. Also, the periods of planets farther from the sun are greater. The earth, therefore, moves at a faster rate than Mars, Jupiter, or Saturn, and passes each of these planets in its annual journey. On these occasions the planet in question appears to run backward instead of forward, retrograde instead of direct. The backward motion that so bothered the ancients is not real, but illusory.

But although this was the correct explanation, it was not proven so until Galileo began a series of discoveries about the planets which has not ended yet, and perhaps never will. He observed the phases of Venus through his telescope; later, Roemer simultaneously proved that light had a finite velocity and measured the velocity of the earth in its orbit around the sun. Two other famous proofs of the earth's revolution were Bradley's discovery of the aberration of starlight and the measurement of the trigonometric parallaxes of the stars.

At present, the problem of the me-

chanics of the solar system contains no major mysteries, but in other respects we still learn new things about our own planet and about our neighbors as well. Considering them in order of distance from the sun, let us sum up, briefly, our present knowledge of these other worlds.

Mercury is the most difficult planet to observe, but not because of any dimness, for at its brightest it almost equals Sirius, the brightest star. From the Northern Hemisphere, Mercury is rarely seen against the dark night sky, and therefore it appears inconspicuous unless one knows when and where to look. With a telescope, it is best observed in full daylight. Surface markings have been seen and sketched by Schiaparelli, Barnard, Antoniadi, and others. The markings are very vague and ill-defined, so the work of these various observers does not bring consistent results.

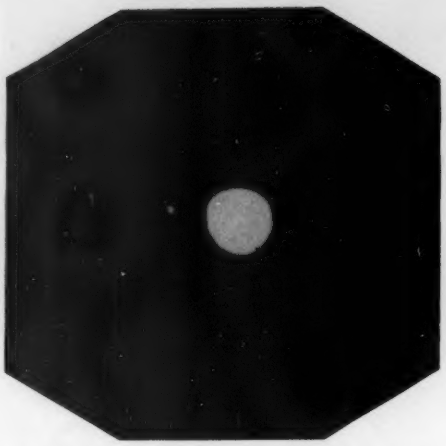
It seems to be generally agreed, however, that Mercury spins on its axis in the same period in which it goes around the sun. Consequently, one side is turned toward the sun perpetually, the other is turned away. If there is any atmosphere, and this is most doubtful, it must be extremely thin. With no protection from the glaring sunshine, the temperature on the sunlit side rises to as much as 770° F. and on the dark side it drops nearly to absolute zero. The high temperature results partly from the fact that Mercury is only 4/10 as far from the sun as we are.

Venus presents a picture that is not nearly so extreme. Here is a planet almost the same size as the earth, in fact, you might call it the earth's sister. Today's large telescopes, with the help of photography in different wave lengths of light, permit us to make out irregular markings on Venus of an extremely ephemeral character. These are taken to represent clouds in the atmosphere of Venus, as it is certain that we do not see the planet's real surface.

The rotation evidence for Venus is negative. That is, spectrographic studies show no evidence of rotation and the inference is that the planet turns very slowly, in not less than two or three of our weeks, but not so slowly that one face is constantly toward the sun. The temperatures on the two sides are about −9° F. and 120° to 140° F.—not so extreme as on our own earth.

These two planets are nearer the sun than we are, and on occasions they transit the sun's disk. Beyond our orbit lie Mars, Jupiter, and Saturn, visible to the naked eye; and still farther out are Uranus, Neptune, and Pluto, which all came into the fold only after the telescope was invented.

Mars is a small planet of not much more than half the earth's diameter. Even though Mars comes close to us, for a principal planet, a telescope rarely reveals as great detail as many enthusi-

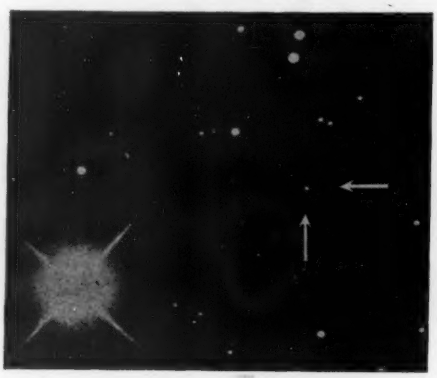


Neptune, the planet discovered by mathematical calculation, has only one satellite, named Triton. The planet's image is here much overexposed.

asts would have us believe. Enough markings are definitely found, however, to promote speculation on their nature and origin. The polar caps, the blue-green markings, the wide red-brown stretches of Martian landscape—what are they? And those thin lines making a crisscross pattern, which are so pronounced on the drawings by Percival Lowell? Do they indicate conditions favorable to life—is Mars inhabited? We do not know. Atmosphere and temperature are not as favorable for life as they are on this planet of ours, but we cannot say definitely that life on Mars cannot be. For a recent illustrated account of modern observations of Mars by Lowell Observatory astronomers, see *The Telescope*, Sept.-Oct., 1940.

We do know that the Martian day is slightly more than a half hour longer than our own, that the year is nearly twice as long as ours. Mars is in some respects more similar to the earth than any other planet.

Jupiter is the giant planet of our solar system. It, too, was grist for Galileo's telescopic mill, for he found Jupiter's four bright satellites—the first "discovered" bodies in the universe. It does not require a large telescope to see them and the markings on the planet itself, which look like stripes parallel to



Pluto, outermost planet, appears as a very faint star, indicated by the arrows. The bright star is Delta Geminorum.

the equator of Jupiter, and are interpreted as cloud belts in its atmosphere. The spectroscope tells us that here are found two gases, ammonia and methane. By inference we believe that water may also be present, but not as a liquid; it must be ice far below the striped atmosphere of the giant world.

Saturn is in many respects similar to Jupiter. In size it is just below Jupiter; in color, slightly richer in yellow; in markings it has the same bands parallel to the equator. But in one respect it differs not only from Jupiter, but from every other known object within our view. Saturn has a wide, flat ring around it—three rings really, if we note the divisions between them—"everywhere separated from the planet," as described by Huygens, the discoverer, in 1655. This ring system, too subtle for Galileo's inferior telescope, makes Saturn the most beautiful single object in the sky when viewed through a telescope. The rings are composed of many tiny meteor-like objects, each traveling independently around the planet, but so closely packed as to present the appearance of a smooth surface. However, bright stars have been seen right through Saturn's rings.

Uranus, next planet beyond Saturn, and twice as far away from the sun, is just on the edge of visibility with the naked eye, but is usually first found by observations with binoculars. This distant planet was discovered by William Herschel in 1781, who called it Georgium Sidus, or George's star, in honor of King George III. The people of that day, and for many years afterward, called it Herschel, but finally the name, Uranus, proposed by Bode, became universal.

Observations of Uranus led to the discovery of Neptune about a century ago. It resembles Uranus in many respects, and together they are like Saturn and Jupiter in having atmospheres of largely methane and ammonia, the former being most abundant. These giant planets spin rapidly. A day on Jupiter, or Saturn, or Uranus, lasts only about 10 hours, and on Neptune it is about 16 hours long. The number of satellites diminishes as we go outward: Jupiter has 11, Saturn has nine, Uranus, four, Neptune, one.

The most distant member known in our planetary family is Pluto, discovered only 13 years ago at Lowell Observatory. Very little is really known about this frigid world on the dark edge of the solar system, except that it is probably smaller than the earth, and takes nearly 250 years to go around the sun. It is a yellowish object of the 15th magnitude, at present situated in the constellation of Cancer. Its average distance from the sun is about 40 times the earth's. So perhaps we should not even call Pluto a neighbor.

BEGINNER'S PAGE

By Percy W. Witherell

Asteroids — Planetoids: II

YOU may wonder what is the use of correctly determining the orbits of so seemingly unimportant objects as the asteroids about which we talked last month. However, as in human affairs, the apparently insignificant is exalted just because of its peculiar differences from the average run of the pack. One of these peculiarities is that some of the little asteroids come nearer the earth than any other permanent celestial bodies except the moon.

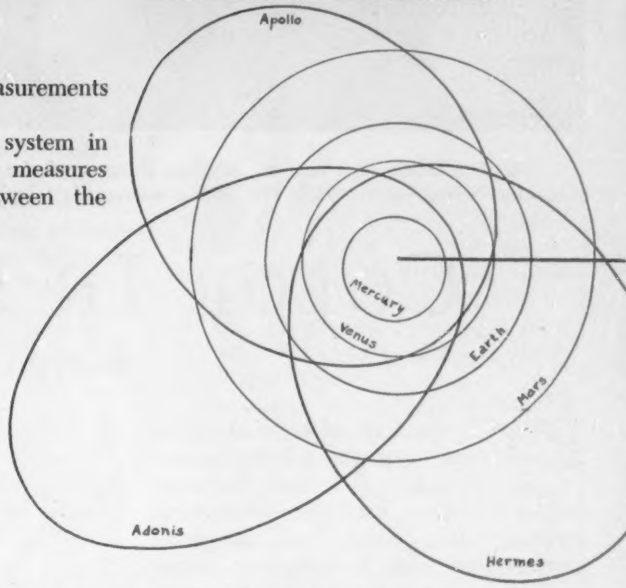
Tiny Hermes, the last planetoid mentioned for its size last month, is well named, for in October, 1937, it moved five degrees per hour across the firmament, taking only nine days to rush completely across the sky, beat the observatories which had been notified by wire, and was caught only by accident on a patrol-camera plate. Consequently, little is known of its orbit, but we do know that Hermes came within 600,000 miles of the earth.

Other small asteroids also come "close" to the earth. Apollo calls on Venus and passes the earth about two million miles away, and Adonis approaches nearly as close. Amor made three trips around the sun between 1932 and 1940, when it was rediscovered. These asteroids' orbits, as might be expected, range from nearly circular to elongated ellipses. The latter are changed considerably when they pass near Jupiter or Saturn.

But of all the small asteroids, Eros has the greatest value to astronomers. It comes inside the orbit of Mars and is only about 14 million miles from the earth at intervals of 17 years. It is then so close that observations made at opposite ends of the diameter of the earth would show one minute of arc difference in its position among the stars. As the distance between observatories is known, this base line allows the distance of Eros to be accurately determined by the usual methods of triangulation. Of course, in practice, shorter base lines than the earth's diameter must be used, but the angle is still of the same order of size, and capable of precise measurement.

You exclaim, what is the use of measuring precisely the distance of such a small object? Let us see. Suppose you had looked over a new house and wanted to draw a plan to show your better half all its good and bad points, and were not in the habit of carrying a foot rule with you. A handy piece of lath would serve as a measure and show the *relative* dimensions in a satisfactory manner. If you wished to put feet and inches on your plan, a comparison of your lath unit of measurement with a foot rule would soon enable you to put down ***absolute*** dimensions, even though you had made the actual measurements using only the lath.

In the universe (the solar system in particular) one of the handy measures is the *average* distance between the earth and the sun, known as the *astronomical unit* (A.U.). By applying Kepler's third or harmonic law to observations of the period of revolution of any planet around the sun, we can express that planet's distance from the sun in terms of the astronomical unit.



Asteroids such as Hermes, Apollo, and Adonis, travel in orbits of high eccentricity. Therefore, they not only cross the orbits of the earth and Mars, but they approach the sun nearer than Venus.

For example, we have long observed the period required for Jupiter to revolve around the sun to be 11.9 years (roughly, 12 years). Kepler's third law, in its simplest form and neglecting the planet's mass, states that the square of the period (in years) is equal to the cube of the mean distance of the planet from the sun (in A.U.). 11.9^2 is 141.61, and the cube root of this is 5.2+. The mean distance of Jupiter is 5.203, and this number represents astronomical units. To see for yourself, try the computation for a few other planets. Square the periods and cube the distances, and note how nearly the results agree in each case:

Venus	265 days	0.723 A.U.
Mars	1.9 years	1.524 A.U.
Saturn	29.5 years	9.529 A.U.
Pluto	247.7 years	39.457 A.U.

Of course, in the case of Venus, you will have to divide 265 by 365¼ and square the resulting decimal.

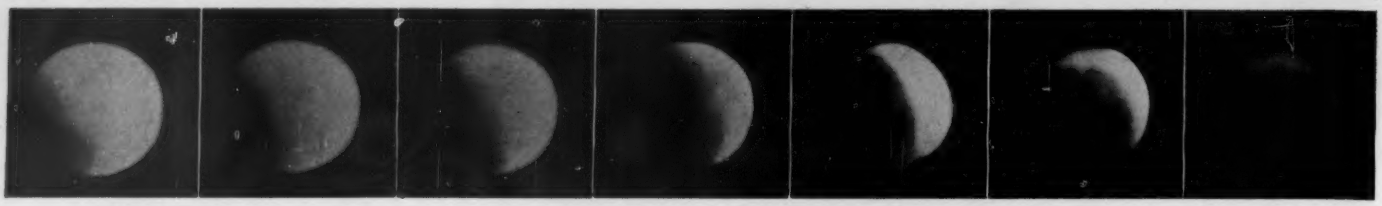
It is now evident that a better determination of the length of the astronomical unit results in a more accurate knowledge of the entire scale of the solar system and of the linear dimensions of the orbits of other planets as well as of our own. When Eros, presenting practically a point image capable of being observed accurately, makes one of its close approaches, its distance from the earth can be obtained. Since its relative distance from the sun (average 1.46 A.U.) is known by Kepler's third law, it is a simple matter to compute the linear values of both these distances.

The importance of this matter is shown by the work of the Astronomer Royal of England, H. Spencer Jones, who took 10 years to reduce the worldwide observations of the approach of Eros in 1931, when the planetoid was within 16,200,000 miles of us. Fortunately for the average man, the round figure of 93,000,000 miles, which had long been commonly used, proved to be more accurate than the 92,870,000 which was the value previously accepted by astronomers. It is still subject to further correction, but we are undoubtedly close to the true value now—thanks to Eros.

Only a few large asteroids show any disk even in big telescopes, so only from their apparent brightnesses and by estimating their reflecting powers can we determine their probable dimensions. As their surface gravities are small, they have no atmospheres, and appear to be gray, rusty red, or brownish. Vesta, however, is white and its surface is porous, as if composed of dust or fragments of meteors.

That many asteroids are in rotation and are irregularly shaped is shown by sudden variations in their brightnesses. When near the earth in 1900, Eros decreased in brilliance 1.5 magnitudes in 79 minutes and later returned to its original light in 60 minutes. Eros' light variations seem best explained by a brick-shaped mass about 14 miles long and four miles wide, rotating about an axis perpendicular to its greatest surface.

What is the origin of these whirling fragments—these "flying mountains"? If they came from plastic masses rotating in space, they should have become spherical as they solidified. More likely, they are (along with meteors) the fragments of a succession of disruptive explosions of a small planet, perhaps originally the size of Mars. Jupiter, which still controls the orbits of the asteroids to a large extent, may have been the power which possibly caused such a catastrophe.

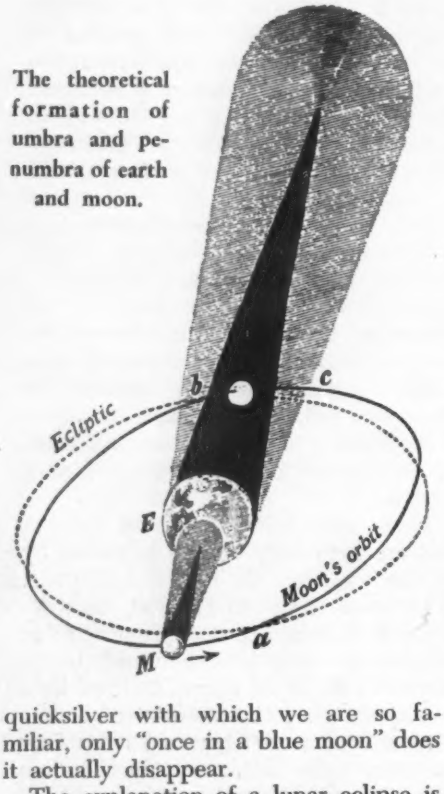


With a small Pilot camera, William Burgess, of the Junior Astronomy Club, took this series of pictures of the lunar eclipse on November 7, 1938. He used a homemade telephoto lens; long exposures caused blurring of three images on the right.

COLOR IN LUNAR ECLIPSES

BY MARTHA GODDARD MORROW

PEOPLE are inclined to think of an eclipse of the moon as being a complete "blackout." Indeed, the word *eclipse* is derived from the Greek words meaning "leave" and "out," so many persons have come to believe an eclipse of the moon an occasion when the moon is left wholly without light, that is, hidden from view. In reality, however, the moon is visible during an entire eclipse, and although it is often seen as a dark reddish-brown instead of the shining quicksilver with which we are so familiar, only "once in a blue moon" does it actually disappear.



The theoretical formation of umbra and penumbra of earth and moon.

The explanation of a lunar eclipse is not so simple as an elementary diagram of the umbra (full shadow) and penumbra (partial shadow) would lead us to believe. Actually, the entrance of the moon into the earth's penumbra makes no perceptible change whatever in its brightness, but as it approaches the edge of the umbra, the moon becomes noticeably less brilliant. When the moon enters into the shade of the umbra, the latter's curved edge seems definitely black, but rarely is the moon hidden from view. During a total eclipse, when the moon is entirely within the umbra, the moon shines with a dull, reddish light, and even the deepest part of the shadow usually contains some light. It is only by consideration of the refraction of light by the earth's atmosphere that we can account for the colorfulness of this phenomenon.

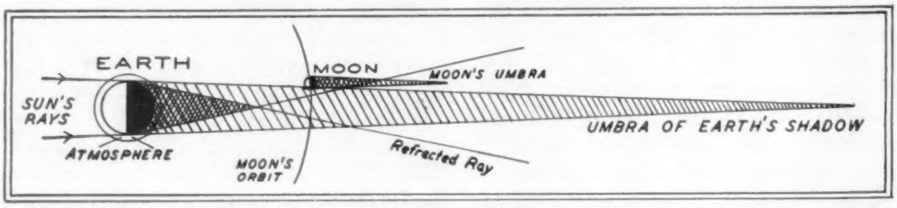
The accompanying diagram shows the effect of refraction on the umbra caused by the light from the sun shining upon the earth: the penumbra is temporarily disregarded. The familiar umbra is not completely void of light because the atmosphere of our planet, acting as a prism, tends to bend, or refract, the pure white light into the dark cone. Some of the light rays are bent slightly; others are refracted as much as one degree or more. Within this lies a cone of total darkness which the light refracted by the earth's atmosphere does not reach. By geometric calculations it is found that the length of the cone from which sunlight is entirely excluded is about one fifth the length of the umbra. This distance is only 170,000 miles—about three quarters of the distance of the moon when it is nearest to the earth. Hence, the moon would normally be expected to shine dimly during an eclipse with whatever light, refracted by our atmosphere, is able to reach the satellite.

Inevitably, and as a consequence of its refraction of the white light, our atmosphere also separates the pure sunlight rays into the various rainbow colors of the spectrum: violet, indigo, blue, green, yellow, orange, and red. Most of the rays at the blue end of the spectrum, the rays which by their nature are the most easily diverted from their path, are scattered by dust particles into the earth's atmosphere. The red and orange rays, being the least easily deflected colors, pass beyond the earth's atmosphere into space. During an eclipse some of these rays eventually reach the moon, which in turn reflects them back to us, so we see the moon as red or orange.

The effect of the refraction of light upon the penumbra is less noticeable. Instead of giving rise to a play of colors on the moon, it tends to make the edge of the penumbra less distinct, so that when the moon enters the penumbra, we are not immediately aware of the gray veil passing across it, but notice the darkening effect as the moon gets nearer the umbra.

Only when the earth's atmosphere is unusually dense with clouds or a large amount of dust particles will most of the light be cut off during a total lunar eclipse, and the moon then appear a smoky reddish-brown, or seem to disappear completely. The effect of volcanic dust haze, which fills the air for months following an eruption, is particularly noticeable. In the eclipse of 1884 following the eruption of Krakatoa, practically no light was able to pass through our atmosphere, and the moon appeared a dark, dull red; the seas on the moon as brownish spots, very dark; and the mountain peaks as brilliant points with slight red halos.

In general, the moon will take on a red, or red and orange glow during an eclipse, but occasionally, when the earth's atmosphere is unusually clear, yellow and even green have been known to appear on the moon. The red, which rays are bent the least, would normally appear on the outer edge of the umbra and nearest the sunlight. Shading through orange and yellow, the green light would come toward the center of



Here the moon is shown slightly immersed in the umbra of the earth's shadow. Note that some light is refracted by the earth's atmosphere into the moon's own umbra!

the umbra, and be visible during the middle of the eclipse. Some of us will recall seeing green shading in the umbra of last summer's vivid eclipse. D. C. Wysor, of Ridgewood, N. J., writes of the August eclipse: "I did not notice this green band until the moon was nearing totality...it really stood out in marvelous beauty. I would not say that it was as dark a green as the darkest of the red was dark red, but it was unmistakable, nevertheless."

Sometimes the color sequence of an eclipse does not follow the usual order. During last summer's eclipse, the green, not the red, was noted to appear toward the sunlight. In order to explain this discrepancy, we must take into account the fact that some of the light rays are transmitted and refracted by the atmosphere close to the earth, and other rays, by the outer extreme of our envelope of air where the index of refraction is less and there is more chance of the yellow and green getting through. Thus, it might happen that the yellow and green transmitted by air on the outer edge of the atmosphere would be bright enough to be visible on the moon, while the atmosphere close to the earth's surface might produce red which would lie in the center of the umbra. A varying arrangement of colors is thus possible, depending on the condition of the earth's atmosphere at the time of the eclipse.

In the *Annals* of the Harvard Observatory, the eclipse of 1891 is described as follows: "The red color appeared upon the northern limb soon after totality began, making the southern limb appear greenish by contrast. The western limb was yellow, and the eastern invisible."

Irregularities in the lighting and color of the moon during an eclipse are very marked, and there appear to be variations in the denseness of the shadow itself. The cause of these variations in brilliancy is usually attributed to the different reflective powers of the moon's surface. This might account for the eclipse of 1860, which is quaintly described as "nothing so like as a red hot penny with a little white hot piece at its lower edge."

The curved shadow cast by the earth upon the moon on entering and leaving the umbra is frequently irregular and hazy. Some astronomers explain this by the fact that the edge of the earth's shadow crosses irregularities in the moon's surface and, therefore, itself appears to be irregular. When the shadow-arc is seen through a telescope (which clears up much of the haziness), there appears much more uniformity in the edge than when viewed with the naked eye.

After an intensive study of recordings of eclipses, Willard J. Fisher ("The Brightness of Lunar Eclipses, 1860-1922," published by the Smithsonian Institution) found that on the whole, winter total eclipses are inclined to be very bright, spring ones dim, and autumn and summer displays intermediate. In general, the southern zone of the earth's shadow has been observed to be brighter than the central, and the central brighter than the northern zone. This peculiarity may be due in part to the fact that there is a large amount of desert and volcanic dust in the Northern Hemisphere of the earth, whereas the Southern Hemisphere, being mostly sea, is comparatively clear.

The same eclipse may be described by observers in different parts of the world as brilliant, clear, and very dark. These variations are undoubtedly due to the local atmosphere through which the moon is being watched. A general haziness would make the moon appear dim and lifeless to one person, whereas another observer might be thrilled with the rich coloring which he is able to see from his vantage point.

The beauty of a lunar eclipse has filled people with wonder since the earliest times. Now that modern science has helped us more nearly to understand the cause of the moon's illusive coloring during this phenomenon, we can find more exciting than ever these instances when the moon's visage is veiled and there is "blood on the moon," or when the moon seems to have acquired tints of a celestial rainbow.

The lunar eclipse of July 16, 1935, photographed with a 12-inch reflector by L. J. Wilson and others. Note the detail in the shadow.

Amateur Astronomers

METEOR COMPUTATIONS

Oscar E. Monnig, editor of the Texas Observers' Bulletin, suggests H.O. 214, the well-known tables of altitude and azimuth used by navigators, for quick computations in graphical solutions of meteor heights. Observations plotted against the stars must be converted from right ascension and declination to altitude and azimuth, which is exactly the navigator's problem. Although H.O. 214 consists of many volumes, each covers 10 degrees of latitude, and costs but \$2.25; for instance, says Mr. Monnig: "The ordinary worker would need only one volume, covering the latitudes within which he ranged; thus, Vol. IV, latitudes 30° to 39°, inc., serves well for the Texas-Oklahoma region . . . . The whole job of transforming an observation would take hardly over a couple of minutes, which is ideal for observers working on real heights and wanting quick, graphical solutions."

OCCULTATION PREDICTIONS

Harvard Announcement Card No. 647, dated January 4th, quotes from a letter from Capt. J. F. Hellweg, Supt., U. S. Naval Observatory:

"The American Ephemeris contains predictions of occultations of all stars brighter than magnitude 6.55 for four stations in the United States. On account of the present scarcity of observations, predictions of additional occultations in 1943 for the three eastern stations have been prepared and will be furnished by the U. S. Naval Observatory upon request."

AMATEUR ASTRONOMERS ASSOCIATION
New York City

On February 3rd, Dr. Robert I. Wolff, of the College of the City of New York, will speak on *Celestial Navigation,* a topic of great current general interest. *Our Trembling Earth* will be discussed on February 17th by the Rev. Joseph Lynch, S. J., head of the seismology department at Fordham University.

The public is cordially invited to these lectures, which are held at the American Museum of Natural History at 8:15 p.m. Information about A.A.A. classes, field trips, and other activities may be obtained by writing to the secretary, George V. Plachy, at the Museum, or by inquiry before or after the lectures.

TULSA ASTRONOMICAL SOCIETY

This society meets on the second Tuesday of each month at Holland Hall, 2640 S. Birmingham Place, at 8:00 p.m. The president is V. L. Jones, telephone 4-8462, and all interested persons are invited to communicate with him regarding membership in the Tulsa group.

THE MOON AS A SOURC

By H. H. Nininger, *Colorado Museum of Natural*

PART I

THE suggestion that the moon has been the source of tektites is not, in itself, new. Long ago it was hypothesized that lunar volcanoes had thrown these blobs of glass to the earth. Promptly, however, the fatal objection was raised that whereas our satellite has been cold and dead since early geological time, tektites are generally recognized as of comparatively recent origin. The hypothesis herein set forth is not troubled by the deadness of the moon, for it finds an ample propelling force in the meteorites which blast that inactive body, sending forth salvos of fragments, some of which, under favorable conditions, reach the earth.

The idea came to the writer while attempting to analyze generally accepted facts pertaining to the moon's surface. On the basis of various findings, chiefly those set down by the Moon Committee of the Carnegie Institution of Washington, I was attempting to picture to myself the probable nature of moon rock. After I had satisfied myself as to its probable color, texture, composition, and fragmentary nature, it suddenly dawned on me that these characteristics were just about the same as those noted in a newly acquired collection of tektites. Realizing that recent volcanic activity on the moon would be an absurd assumption, I began to look for an agency which could account for the arrival on our planet of samples from our nearest neighbor.

Tektites are small bits of natural glass which have been found on certain areas of the earth between latitudes 40° south and about 50° north. They show unmistakable evidence of having been shaped while in a plastic condition. Few of them, if any, show the peculiar fusion crust overlying an unmelted interior, which is so constant a characteristic of meteorites. They differ chemically and structurally from any known terrestrial glasses, or for that matter, from all artificial glasses. And they seem to bear no necessary chemical relation whatever to the particular terrains on which they are found. The distribution of tektites almost compels one to seek for them an extraterrestrial source, yet that same distribution, in certain important particulars, constitutes one of the strongest arguments against their being considered as true meteorites.

Each deposit encompasses a large area of from several thousand to as much as two million square miles. These areas are usually rather generously sprinkled with tektites. They are often far removed from any volcanic region.

The truly puzzling nature of these apparently foreign blobs of glass is evidenced by the many ideas that have been suggested for their origin. A number of these are:

a. Terrestrial lava bombs.

b. Terrestrial volcanic bubbles carried by the wind.

c. Lava bombs from lunar volcanoes.

d. Glass of ancient artificial making.

e. Gizzard stones of ancient birds.

f. Artifacts of ancient man.

g. Concretions in limestone.

h. Colloidal bodies formed from sediments by the action of humic acid.

i. Atmospheric dust fused by lightning.

j. Terrestrial sediments fused by lightning.

k. Soil fused by fires of various terrestrial origins.

l. Glass meteorites.

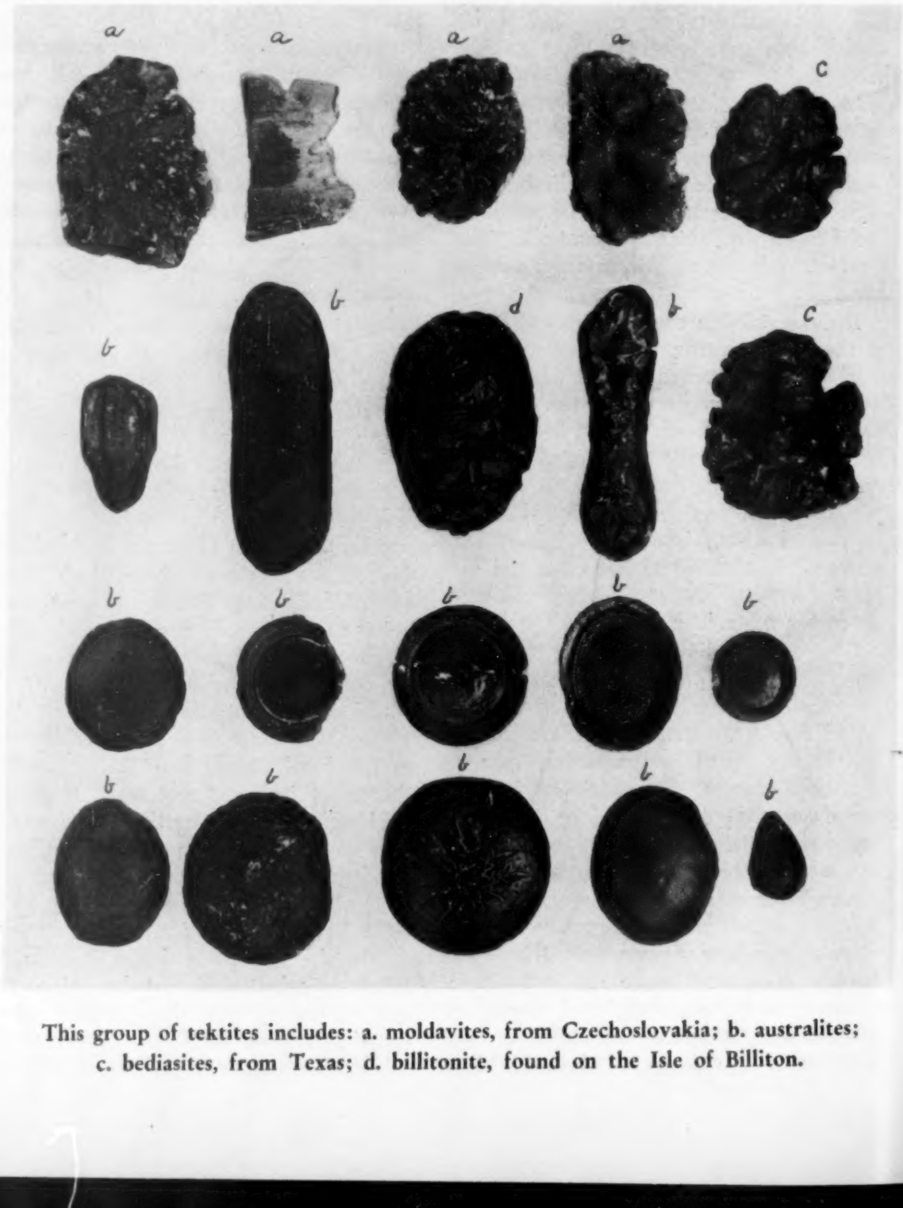
m. Nodules from light-metal meteorites.

n. Silica fused by large meteorite impacts on the earth.

o. The recently submitted "astronomical theory" of Dr. W. Carl Rufus.

Few of these hypotheses are at present in sufficient favor to deserve much discussion in the light of now well-known facts, with which must harmonize whatever may be the finally accepted theory as to tektite origin. Well-established and significant facts include these:

1. Tektites from the several known localities closely resemble each other as to internal structure and composition.
2. Tektites from a given area exhibit certain features in common as to form and color, while those from other areas may exhibit different group characteristics.
3. Those from a given locality generally show evidence of a common age.
4. Those from different localities sometimes show great differences in age.
5. All are of relatively small size.
6. As to composition, they bear no necessary resemblance to the terrain on which they are found.
7. They are almost wholly glassy, though some contain fragments of unfused or partially fused material. They consist of from 70 to 80 per cent silica; are harder than artificial glass; and have a lower index of



This group of tektites includes: a. moldavites, from Czechoslovakia; b. australites; c. bediasites, from Texas; d. billitonite, found on the Isle of Billiton.

CE OF TEKTITES

of Na al History

refraction than artificial glasses—1.48, 1.49, as against 1.5 or higher.

8. They differ from all known terrestrial glasses, both natural and artificial.

9. A few have been known to contain nickel.

10. The specific gravity of tektites ranges from 2.3 to 2.5.

11. They differ markedly in structure and composition from any known meteorite.

12. Great meteorite falls on the earth have produced silica-glass by fusing the terrestrial sediments. In some respects these glasses resemble tektites.

13. Their structure strongly suggests that they have congealed from a molten or plastic state while spinning freely in space or in a gaseous atmosphere.

14. Some of the forms (buttons and lens-shapes sometimes bearing flanges) strongly suggest that they have been shaped by passing rapidly through the air while an outer zone was in a plastic state.

15. There is strong evidence that the bulk of the australites originally congealed in spherical or subspherical form.

16. Certain of their surface markings have been definitely ascribed by experienced students to aerial surface fusion—pitting and furrowing similar to that in meteorites have been found in rare instances.

17. Certain other of their surface markings appear to be definitely due to terrestrial corrosion.

18. Many tektites show two distinct phases of formation. (a) The body of the mass seems to have cooled from a melt. (b) The outer zone, though a true glass, appears to have been subjected to a second superficial heating.

19. Tektites are found on very limited portions of the land surface of the earth, and these all lie between latitudes 50° N. and 40° S.

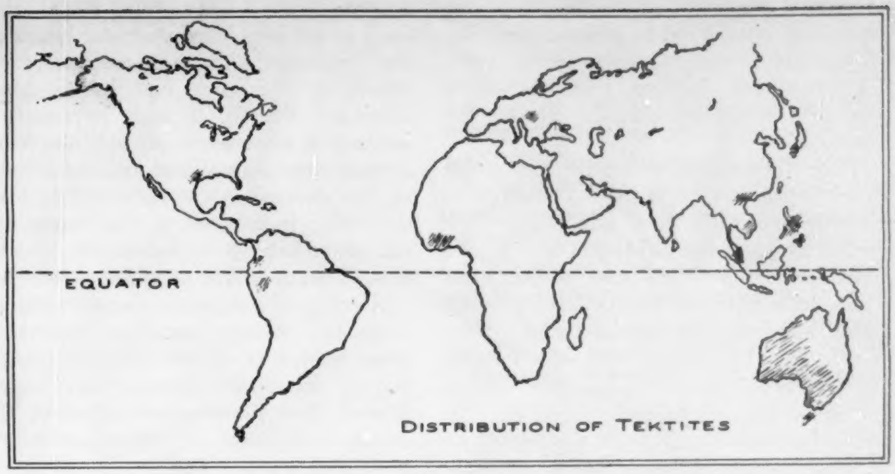
20. Tektites show no preference for any particular geological formation, topographical form, or terrain of any special composition.

21. The few areas which have yielded tektites are on the average very much larger than the areas encompassed by our greatest known meteorite falls.

22. We have no proven record of a witnessed fall of tektites; although a few persons have laid claim to such experience.

23. Their known distribution in and upon the soil is in most instances not compatible with the idea of their recent arrival.

OF the 15 hypotheses listed earlier in this article, only six seem to deserve special attention. These are *j*, *l*, *m*, *n*, *o*, and *c*. The strongest advocate of the theory that tektites are in reality only a variety of fulgerites (*j*) has been Dr. Virgil E. Barnes, who described the bediasites from Texas. He admits that this hypothesis is not satisfactory in all respects, but finally concludes that "practically all of the evidence now indicates that tektites will be proven fulgerites." He believes that they represent the effects of lightning in various types of soil, shale especially.



Shaded areas show roughly the portions of the world where tektites have been found.

We find, however, that six of our list of significant facts definitely argue against the fulgerite hypothesis. These are Nos. 1, 3, 6, 9, 18, and 19. One seemingly insurmountable difficulty lies in the fact that if a group of tektites such as those from South Australia had been formed by lightning, there should certainly be found evidences of great differences in age, yet students agree that the australites as well as other tektite deposits show convincing evidence of uniformity of age within the area. Also, the australites are found alike over a score of different types of country rock, yet all of the australites are almost identical in composition.

Again, there are many great areas where the soil conditions and the prevalence of lightning are quite as favorable for the forming of "fulgerite tektites" as that where Dr. Barnes' bediasites were collected, yet which have yielded no tektites. Many of these areas have been very carefully searched for meteorites by the local residents during a number of years. These people have sent to the American Meteorite Laboratory many thousands of stones in the hope that they were meteorites. Hardly any kind of terrestrial object has failed to arrive. Even fragments of building brick, bottle glass, crockery, cinders, lumps of tar and wax, quite a number of fulgerites, even desiccated potatoes, but never yet a tektite! Because of our many years of experience in field work, we would not venture to say that there are *no* tektites in the great plains area of Colorado, Kansas, Nebraska, and north Texas, where our field efforts have been chiefly carried on, but we have a feeling that at least some tektites should have shown up from this area where lightning is so prevalent, if they are of fulgeritic origin. Several other very significant facts seem to render the fulgerite hypothesis untenable, for example, the limitations of tektite finds to the lower latitudes. Lightning is surely prevalent in many areas north of the 50th parallel in the Northern Hemisphere and south of the 40th in the Southern, but no find has yet been reported outside of these bounds.

The forms of tektites are in no case comparable to any known fulgerite. The nearest approach is that referred to by Barnes in connection with a broken power line; but no duplication by natural process has been cited.

That tektites are glass meteorites (*l*) deserves attention for the reason that it has had so many advocates. However, as Dr. Barnes has clearly pointed out, this hypothesis falls far short of deserving so wide a following. The surface sculpturing on tektites has sometimes been cited as evidence of their meteoritic character. But even though these markings superficially resemble those on meteorites, they have in many cases been proven to be due to corrosion instead. Their distribution alone constitutes a powerful objection. Hundreds of meteorite falls have been studied as to distribution, but none even remotely resembles that of tektites, either as to the extent of a given area or as to their restriction to certain latitudes. Again, two million tektites are estimated to be present in Australia alone. The evidence is that tektites are far more abundant than are meteorites. Yet more than 500 meteorite falls have been witnessed, involving thousands of individual stones and irons, and not a single proven case is on record where a tektite has been seen to fall. Most important of all, the unique fusion crust which in meteorites is congealed over an unheated interior, thereby setting them apart from all other known natural objects, stands in striking contrast to the conditions found in tektites. *Tektites are certainly not meteorites.*

The persistent efforts to induct tektites into the family of meteorites may be explained by the following facts: Tektites are unlike other terrestrial objects. Their distribution suggests ex-

traneous origin. They evidence a free spinning period while plastic, and unfortunately, many persons—even some scientists—still believe that meteorites fall in a plastic condition, a very erroneous notion.

The light-metal meteorite hypothesis (*m*) represents an ingenious attempt to hurdle the difficulties which have always harassed the adherents to the glass meteorite hypothesis, and at the same time to escape the inconsistencies which any suggested terrestrial origin must face. Dr. Charles Fenner has summarized this hypothesis as follows:

"At a time 'geologically recent but historically remote,' the earth was visited by a large and widespread swarm of combustible metallic meteorites. The swarm was not less than 30 tons, and possibly 300 tons, in total weight, containing (say) ten per cent of siliceous material. The component bodies travelled across Australia in a wide and irregular formation on a front of 1,000 miles or more, at a height of 80 miles or less, burning as they went. Possibly some were burnt up relatively early, while others entered the atmosphere later and farther on. The period of transit of the swarm across Australia occupied at least 45 seconds and at the most five minutes. Their residual incombustible siliceous content was shed in molten glass blobs, these being for the most part swept backward by the rush of air from the rotating parent bodies, and thence shot outward in many directions. The glassy blobs, to the number of from one to ten millions, averaging about three grams in weight, sped to the earth, rapidly rotating and undergoing ablation and flow from their forward parts, reaching the earth's surface in from three to six seconds, having been chilled to solidity during the last portion of their flight. The blobs, as they formed, instantly assumed the shapes of spheres and allied forms common to rotating liquid bodies, and these by ablation were reduced to lens, button, and other form-types known as australites. They were thus distributed in an irregular way over the southern portion of the Australian continent."

Serious objections to this hypothesis are: First, no such meteorite as is here hypothesized is known either as a specimen or from spectrograms made of meteors. Second, if such were their origin, there should have been found some examples of tektites in association with these assumed light metals. It is hardly conceivable that the refining process should have been so complete as to leave us only blobs of pure glass. Third, a meteorite does not really *burn up* in the atmosphere. The time is too brief and oxygen is too scarce. It merely disintegrates by frictional ablation[1] or by evaporation. The high surface temperature is sufficient to evaporate glass quite as readily as it does the other constituents. In the Estherville "pellets" the writer has shown (*American Journal of Science*, Vol. XXXII, July, 1937) that even in the very latest stages of luminous flight silicates and nickel-iron were removed at the same rate by frictional ablation. Fourth, if such hypothetical meteorites exist there should also exist intermediate forms, and therefore some of the thousands of falls which have deposited meteorites in and upon the soil should have revealed the association of tektites and meteorites.

A study of meteorites demonstrates no fact more clearly than that they have been subjected to no refining process during the flight through our atmosphere. The portion that survives the ordeal of ablation is quite representative of the whole.

Objections to Dr. L. J. Spencer's hypothesis (*n*) that tektites may have been formed in connection with the impact of large crater-forming meteorites on the earth are: First, no true tektite has been found associated with any of the 30 or more proven meteorite craters. Second, in none of the great tektite areas have there been identified any meteorite craters. Third, fused silica glass in considerable quantities has been found associated with meteorite craters but it differs from tektites both chemically and structurally. Fourth, "fused country rock" in considerable abundance has been found associated with silica glass around the Henbury and Wabar meteorite craters. None of this material has been found associated with tektites. If tektites were formed as a result of meteorite impact we should certainly expect such an association.

There is a modification of the glass meteorite hypothesis which we have not listed. It assumes that at one time the earth passed through a region of space which was infested with glass meteorites. Another version has it that two such swarms were encountered and that these encounters were responsible for all of the tektites received by our planet. Such limited encounters were supposed to explain the distribution of tektites within a narrow zone of equatorial latitude. This is usually referred to as the great circle hypothesis.

Since this suggestion assumes the earth's encounter with swarms of glass meteorites, we may of course offer the same objections as have been offered to the meteorite hypothesis. If we wish to consider merely its bearing on tektite distribution, the new hypothesis which in this paper is being proposed seems to fit the facts even better.

The recently proposed astronomical theory of Dr. Rufus (*o*) should be considered.

"It is supposed that the small, natural-glass bodies known as tektites were originally derived in major part from the glassy basalt, or tachylyte, which forms the deeper crustal layer of the earth, exposed chiefly on the floor of the Pacific basin, at the time of the fissional separation of the moon; furthermore, that the earthly tektites represent only a small section of the vast swarms of tiny satellites which remained revolving about the earth within the Roche limit, and particularly that section of the satellites having a revolutional period closely coinciding with the period of the earth's rotation. Such swarms would have remained approximately above the Pacific basin, but would have gradually fallen behind and tended to be drawn to the earth, on account of perturbations resulting from the gradual retardation of the moon. Cumulative perturbations and other related factors have caused swarms of these bodies to come down to the earth at widely separated geologic periods in the earth's history, such falls having been particularly extensive along a great-circle route crossing the western edge of the Pacific basin. This circumstance would account for the great quantity and wide distribution of the Indomalaysian tektites especially, which are of almost identical chemical composition, while other showers of tektites came at different geologic periods and varied somewhat in composition and physical appearance."

This explanation would seem to be entirely incompatible with certain known facts. The specific gravity of the moon has been rather definitely calculated at 3.4. It is difficult to see any reason for assuming that a swarm of small satellites left behind at its fissional birth should on the average differ as much as 30 per cent from the moon's specific gravity. The specific gravity of tektites as determined by hundreds of measurements on specimens from various parts of the globe ranges within rather narrow limits between 2.3 and 2.5. Again, it would seem that there should be a more equable distribution of tektites within an equatorial zone of the earth if such had been their origin. In the third place, it would seem that the tektite deposits should on the whole be much older than their present geological relations indicate, because advocates of the fission birth of the moon place that birth antecedent to the formation of a solid crust on our planet. Fourth, we should certainly expect a wider variety as to composition among the arrivals from such a source than are found in tektites. Finally, they should show a far greater range in size.

Let us now consider the suggestion that tektites are small volcanic bombs from lunar volcanoes (*c*). It must be admitted that if there ever was volcanic activity on the moon, that activity was very ancient, for surely the conditions now existent on that satellite are not favorable to volcanism. N. S. Shaler, after 30 years of studying this question, concluded that all of the volcanic activity had ceased on the moon before the fluid mass of the earth had frozen over. It may also be assumed that if volcanism existed it must have diminished gradually, and therefore we should find tektites more and more abundant as we pass to older and older sediments. They should be more numerous in the

[1] *Ablation:* separation and removal of particular rock material by any process or processes acting either mechanically or by solution (Webster).

more ancient deposits until an age were reached in which there would be found only scanty remains of a very large number. Finally, of course, corrosion would have removed all traces of them. If the lunar craters are volcanic, and if any of their ejected materials reached the earth, then we should expect that a far greater amount would have arrived than the deposits of tektites indicate. On the other hand, if, as the present paper proposes, we assume that tektites have been produced on the moon as an accompaniment to meteorite impacts, we have reason to anticipate their scarcity, because our planet has always shielded the side of the moon which faced it from the majority of the meteorites which otherwise would have impinged upon that face.

Summarizing, it would seem that any acceptable theory of tektite origin, in order to be consistent with the structure, composition, and distribution of known tektites, must look to an extraterrestrial source. The same consideration seems to demand with equal positiveness that these objects be assigned an origin different from that of known meteorites. On the other hand, once their internal characters and their distribution are accounted for, we shall find good use for the process of aerial friction which has so prominently impressed itself upon orthodox meteorites; but in the case of tektites this process must be somewhat altered, because, as we have pointed out, tektites show positive evidence of having been in a plastic condition throughout and have not been merely subjected to surface fusion, as have meteorites.

If we can find a situation beyond the limits of our planet where small aggregates of rather light siliceous matter are being liquified or volatilized and allowed to cool quickly while in a free spinning condition, and then can find a process operating to project large swarms of these bomb-like blobs earthward (at very infrequent intervals) at velocities sufficient to produce flowage, but not necessarily surface ablation during their passage through the atmosphere, then it would seem that we are on the way to finding a solution to the puzzling question: Whence come tektites?

The moon is very near the earth (only about 30 diameters removed) and has been found to influence our planet in many ways. The moon is regarded as a cold, dead object, but even so, its nearness and size render it a far greater influence than any of the other astronomical bodies save the sun.

Next month we shall examine this nearest of our neighbors and see if it may serve to help us out in our effort to find the origin of tektites.

(To be concluded next month)

NEWS NOTES

By Dorrit Hoffleit

COMET WHIPPLE 2

Comet Whipple 2 was discovered on December 12th, just as the January issue was on its way to press. So far as average comets go it is fairly bright, but only telescopically. It is *not* expected to attain naked-eye brilliance. An orbit computed by Dr. Fred L. Whipple indicates that the comet passed within 50 million miles of the earth in the latter part of January, when its visual magnitude was predicted between 6 and 7. The closest approach to the sun is expected to occur on February 6th, at a distance of 125 million miles from the sun. Since the available observations cover only a small segment of the comet's orbit, it is as yet impossible to say how far away the aphelion distance is, or what is the period of revolution of the comet.

In the early days of February, people with small telescopes or good binoculars may expect to observe this comet. The predicted positions are (1943 coordinates):

Date	*R.A.*	*Dec.*
Feb. 1	10^h 31.3^m	49° 29′
" 5	10 48.2	51 24
" 9	11 4.8	52 54

Photographs of the comet obtained on December 15th and 16th at the Lowell Observatory are reported to show a tail over one degree long.

NOVA PUPPIS FROM SOUTH AFRICA

News from abroad, even nowadays, sometimes gets here promptly. We have already received a packet of 14 prints from Dr. J. S. Paraskevopoulos at Bloemfontein, South Africa, showing the progress of Nova Puppis between November 13th and 23rd. Apparently all of the major instruments there have vied with one another in an attempt to reveal the secrets of the star. Especially beautiful to the astronomer's eye are a series of nine large-dispersion objective-prism spectra. They add little, however, to what Dr. Dean B. McLaughlin described in the January issue of *Sky and Telescope*.

WORK AT VICTORIA

We have just received the report of the director, Dr. J. A. Pearce, of the Dominion Astrophysical Observatory at Victoria, B. C., for the years 1940-1941. As usual, much of the time at that observatory has been devoted to studies of spectroscopic binary stars and various investigations on the spectra of the hotter classes of stars. Outstanding has been the work of Dr. Andrew McKellar on the identification of interstellar molecules. His work, supported by observational material by Dr. W. S. Adams at Mt. Wilson, yielded the first conclusive evidence for the presence of diatomic molecules in interstellar space, namely of CH (a molecule consisting of one carbon and one hydrogen atom), CN ("cyanogen," a combination of carbon and nitrogen), and NaH (sodium plus hydrogen).

BIRTHPLACE OF NEWTON

At the celebration of the tercentenary of the birth of Sir Isaac Newton, the president of the Royal Society of London, Sir Henry Dale, announced that successful negotiations have been completed for the society's acquirement of the birthplace of Newton. The land which Newton's family farmed has been in danger of being laid waste by quarrying for iron-stone. Owing to the interests of the Royal Society, "the modest manor farmhouse with a small orchard in front of it" (pictured in this magazine last month), in the hamlet of Woolsthorpe, has escaped this hazard. We quote from Sir Henry Dale's address:

"It was here that he returned from his schooling at Grantham, at the age of 16, to take charge of the farm for his mother; and here, to the incalculable gain of science and the world, he showed such incompetence as a farmer that he was sent back to school and thence to Cambridge. It was here, again, that he returned in the autumn of 1665, when the plague drove him from Cambridge; and here, during the following 18 months of quiet exile in the country, his early ripening genius grasped already the essential principles of his major theoretical discoveries."

THE EXPANDING UNIVERSE

A year ago, at the Christmas meetings of the American Association for the Advancement of Science, Dr. Edwin P. Hubble, of Mt. Wilson Observatory, delivered the annual Sigma Xi lecture. His topic was the "Problem of the Expanding Universe." Discussing the observational material, specifically that which seems to tell us that the more distant any galaxies of stars are from us, the faster they are running away from us, Hubble concludes that "apparent discrepancies between theory and observation must be recognized. A choice is presented, as once before in the days of Copernicus, between a strangely small, finite universe and a sensibly infinite universe plus a new principle of nature."

This lecture has been published with beautiful illustrations in the January, 1943, issue of *The Scientific Monthly*, we recommend it to our interested readers.

BOOKS AND THE SKY

THE ORIGIN OF THE CAROLINA BAYS

DOUGLAS JOHNSON. Columbia University Press, New York, 1942. 341 pages. $4.50.

THE "bays" are shallow basins, occupied by marsh or lake, or even dry; often of remarkably regular elliptical or ovoid outline; partly low-rimmed with white sand. They are found in the coastal plain of South Carolina, but extend into adjacent North Carolina and Georgia. They show best in aerial photographs, and in 1933 were described by Melton and Schriever as meteorite craters. The first half of Dr. Johnson's book is an examination of the meteorite hypothesis; this is the part of most interest to astronomers. The second part presents the author's own hypothesis of origin.

He rejects the meteorite hypothesis for the following reasons:

1. No meteorites are found in the area, though they are abundant to the northwest.
2. Incomplete magnetic surveys show no evidence of buried meteorites.
3. The basins are shallow, and the rims, except for the whiteness of the quartz sand covering them, are inconspicuous. This is quite in contrast with Meteor Crater, Ariz., a recognized meteorite crater.
4. There is no disturbance of the adjacent horizontal coastal plain beds.
5. The rims do not contain material thrown out from the basins.
6. There are all gradations between the nearly perfectly elliptical and ovoid bays, which are exceptional, and quite irregular bays, which have no resemblance to craters.
7. The bays are not found in the geologically different piedmont immediately west.
8. The enormous size, up to several miles, of some of the bays.

For these reasons, among others, Dr. Johnson considers the meteorite hypothesis untenable. The argument seems conclusive. From now on it is pretty much what William James calls a "dead option."

The author's own explanation is not simple. He calls it "the hypothesis of complex origin," or the "artesian-solution-lacustrine-aeolian hypothesis." Ground water, and especially artesian water, working along the slightly seaward-inclined beds of the coastal plain and coming to the surface, may have initiated the basins. Solution and sinkhole formation may have co-operated. Wave and current action in lakes which earlier occupied the basins have rounded their shores, and wind has blown clean quartz sand about their borders. Later, marsh has generally replaced lake.

This seems a reasonable explanation of the facts, far better than any previously offered, and it will be the basis for any further study of the bays. Time will tell to what extent it may need modification. It is an interesting example of close scientific reasoning in a field where mathematical exactitude is impossible.

LEWIS G. WESTGATE
Ohio Wesleyan University

DOWN TO THE SEA

LOUISE HALL THARP. Robert M. McBride and Co., New York, 1942. 242 pages. $2.00.

CHILDREN will welcome this interestingly told story of the life of Nathaniel Bowditch, the great navigator. Older readers also will enjoy it, and appreciate the book more because the author has remained true to the facts of Bowditch's life, while presenting them in an easily read style.

My two co-reviewers, aged nine and 12, were both enthusiastic. The younger one tells me the story begins at the best possible moment—with young Nat waking up. This gives the reader a chance to start even with the hero in discovering who and where he is.

Nat, as a boy of eight, woke on a snowy morning in a crowded, poverty-stricken home in Salem, during the Revolution. Yet Nat found his environment full of life and opportunity. Salem was a busy shipping town whose vessels sailed to many distant ports.

Too often these voyages met with mishaps, for chance and guesswork played a large part in navigation. More than any one man, Bowditch changed navigating methods. He changed them toward greater safety so that in another snowstorm, years later, he could bring his own ship safely into Salem harbor. He also simplified methods so that under his instruction all hands, even the cook, learned to be expert navigators.

For those times, Nathaniel Bowditch was a comparatively old man when he first went "down to the sea." His early love of figures, combined with a delicate physique, had led to an apprenticeship in a counting-house from the age of 12 to 21. On the whole, his life was uneventful, spent more in office and study than on the open decks. But the author has made the most of true anecdotes of Bowditch's life, and combined them with vivid glimpses of the background of those times.

Mrs. Tharp has also brought out clearly the driving forces behind the man—his love for mathematics and his practical turn of mind. These led first to the publication of the *American Practical Navigator*—known the world over as "Bowditch"—and later to the translation of Laplace's *Mécanique Céleste.*

The author deserves great credit for bringing out the essential seriousness of Bowditch's character, at the same time that she shows him as a likable human being with his own sense of fun.

The book is clearly printed and illustrated with attractive woodcuts.

PRISCILLA F. BOK
Harvard College Observatory

ASTROGRAPHICS

or First Steps in Navigation by the Stars

FRANK DEBENHAM. Chemical Publishing Company, Inc., 1942. 118 pages. $2.75.

"'I DIDN'T say there was nothing *better*,' the King replied. 'I said there was nothing *like* it.' Which Alice did not venture to deny."

This quotation from *Through the Looking Glass* heads Chapter VIII, entitled "Stereographic Scales," and so aptly describes *Astrographics* that the reviewer is tempted to conclude his remarks at this point.

This charming and amusing book represents a teacher's field day in presenting the methods and principles of celestial navigation that are *not* used in modern practice. Undoubtedly Prof. Debenham, with his wit and humor, can entrance his students in navigation at the University of Cambridge, and undoubtedly his method is highly successful in teaching them the principles of the astronomical sphere and triangle. But his small volume on the subject contains so much extraneous material (the astrolabe, armillary sphere, Gunter's quadrant, the *mathematicall jewell*, and so on), that the beginning practical student will be unable to separate the useful from the illustrative. Unfortunately, too, British usage is sometimes different from American. Eventually, of course, the student will discover that Greenwich mean time and Greenwich civil time are nowadays identical in the British and American *Almanacs*, but not by reading *Astrographics.*

In the hurried wartime teaching of navigation, *Astrographics* can hardly do more than confuse the student. The reviewer can recommend it only to the instructor who seeks to improve the geometrical clarity and charm of his lectures, to the student who has leisure for extracurricular academic pursuits, and to the layman who wishes to amuse himself by playing at navigation with a total expenditure of only $2.75.

FRED L. WHIPPLE
Harvard College Observatory

ASTRONOMICAL ANECDOTES

UNEXPECTED CHRISTMAS GIFT

IN the November, 1941, issue of *Sky and Telescope,* this department concerned itself with two young Englishmen, Edward Pigott and John Goodricke, who observed variable stars together more than a century and a half ago. Now it so happens that in England there is a gentleman, Major George Anne, who is engaged in writing a family history of the Pigotts, and he was referred to the brief notice in *Sky and Telescope* by Miss Kathleen Williams, the very efficient assistant secretary (recently retired) of the Royal Astronomical Society.

Major Anne wrote to the editor, who forwarded the letter to me. In his letter, our English friend asked for references to the connection between Edward Pigott and John Goodricke. I was able to obtain them through the kindness of Dr. Alfred H. Joy, of Mt. Wilson, and to send them to him. In his acknowledgement, he wrote, in part, "I beg your acceptance of the enclosed autograph letter. It is addressed to the father of Edward Pigott." The old letter he sent me was dated "Windsor, Queen's Lodge, July 17, 1782."

Let's go back to the house at 19 New King Street, in Bath, to which a 42-year-old musician and his brother Alexander and sister Caroline had moved early in 1780. In the garden behind the house, on March 13, 1781, this musician caught his first glimpse of "a curious either nebulous star or perhaps a comet" (the planet later called Uranus), through his 6-inch telescope. The name of William Herschel soon became known, and he was visited often by prominent persons, through whom he was elected a Fellow of the Royal Society on December 6, 1781. His sister tells us in her diary that many of the visitors were "philosophical gentlemen who used to frequent the levees at St. James's. . . . Colonel Walsh, in particular, informed my brother that from a conversation he had had with His Majesty, it appeared that in the spring he was to come with his seven-foot telescope to the King."

On Whitsunday, May 5, 1782, William and Caroline Herschel played and sang for the last time in public, in St. Margaret's Chapel, in Bath. Writes Caroline: "The Tuesday after Whit Sunday, my brother left Bath . . . furnished with everything necessary for viewing double stars, of which the first catalogue had just then appeared. . . . A new seven-foot stand and steps were made to go in a moderate sized box, to be screwed together on the spot where wanted. . . . Alex, as well as myself, could learn nothing but that he had been introduced to the King and Queen, and had permission to come to the concerts at Buckingham House, where the King conversed with him about astronomy."

The letter I received as a gift from Major Anne was written by William Herschel while he was living at the court, in this period following his last appearance as a professional musician. The letter follows; it is addressed to Nath. Pigott, Esq^{r}., York, and bears the original seal in wax, the impression of a helmeted head.

"Sir,

I have the honour of your letter; but having been from home, and my return being uncertain, it has not been sent to me till now tho' by its date I find it ought to have come to me near a month ago. I shall be very glad as soon as I return to Bath to repolish the Speculum for you, which you say is tarnish'd; but I fear it will be necessary to have the tube along with it. If you can spare that and will favour me with it I shall do my best endeavours to return the telescope in good order. As soon as I return to Bath I will do myself the pleasure to acquaint you with it.

I do not rightly comprehend your figure of the Moon Sir; for you call the line AB a tangent to the moon's illuminated limb, and also call LC the line of illumination. [Note by R.K.M.: there is a diagram in the letter, pencilled by Herschel.] But it appears to me that SM in that case, is the line of illumination of the Mountain or the illuminating ray. I beg the favour of you, therefore this figure a little more at large. And to express where you suppose the Sun to be placed &c: However I foresee already that the method you intend to point out must be liable to one objection which will render it intirely impracticable. For as these observations [Note by R.K.M.: the determinations of heights of lunar mountains] require a telescope which will bear a very high power, such as from 200 to 500 at least, the field of view can never be large enough to admit on opening of the Micrometer of such an extent as to take in, besides the measure of the mountain, the semidiameter of the moon. The coarsest of my micrometers I use upon the moon, will not open much above 4 minutes; Nor do I think it safe to measure the projection of any mountain with a double eye glass; except both glasses are placed between the wires and the eye, which may be done but is not common. I beg M^{r} Pigott jun^{r} will never wait for a frank to write to me, as I am always equally happy to receive letters without that circumstance. I believe I ought to ask *you* when we may see the new star again [Note by R.K.M.: the planet Uranus]; for as you are furnished with fixed instruments you will most probably see it long before me; I suppose you are now looking out for it. I shall be very glad if you will favour me with your observations on it, especially the time of its opposition & its AR & declination at that time.

There is now printing a long paper of mine on double stars, of which I shall not fail to send you a copy as soon as it is finished in hopes it may meet with your approbation which will give me a very sensible pleasure. I am now at Windsor, where his Majesty desired me to bring my telescope for his inspection. The king has expressed great satisfaction, tho' the weather has been the most unfavourable that could possibly be for astronomical observations. I have had the honour of shewing his Majesty with my telescope some of those very close double stars of my Catalogue which none of the kings own instruments nor those at Greenwich, are powerful & distinct enough to shew, as we have found by tryal. I am with great respect Sir, Your most ob^{t} humble Ser^{t}

W^{m}: Herschel."

This is the letter which I received as a gift from Major Anne, about two weeks before the Christmas just past. I believe I could hardly have chosen, from a bushel of Herschel letters, a more desirable one. R.K.M.

INDEX ANNOUNCEMENT

A title page and working index to Volume I of *Sky and Telescope* is now ready for distribution. It includes author, title, subject and topic references, adding considerably to the usefulness of the year's issues. Because of the increased cost of printing this more elaborate index, a charge of 25c a copy postpaid is made for it, which may be sent in coin or stamps. Please send your orders in promptly. ED.

GLEANINGS FOR A. T. M.s

Designing an Achromatic Objective—IV

(Continued from the December issue)

Spherical aberration. Light passing through a lens near its edge does not come to the same focus as that which passes near the optical axis. It would be possible to eliminate this if we made the lens surfaces aspheric, but this would be unduly difficult from a manufacturing point of view, and it would introduce other, more annoying, aberrations. Spherical aberration is a function of the refractive index and of the ratio of curvature of the two surfaces of a lens, and hence may be removed by proper balance of the curvatures of the two surfaces.

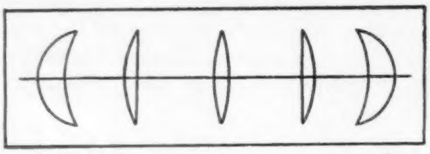


Fig. 8. Lenses of the same total focal length.

As we shall see a little later, the focal length of a lens depends only on the total curvature of both surfaces, and is independent of the distribution of the curvatures of the individual surfaces. All the lenses in Figure 8 have the same total curvatures, hence the same focal length, but the spherical aberration ranges from positive to negative.

We shall define spherical aberration as the distance between the intersection-lengths of the marginal and the paraxial rays in a

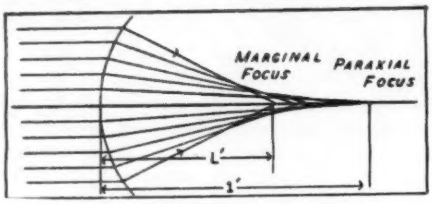


Fig. 9. Spherical aberration.

given lens or lens surface: $l' - L'$ (Figure 9). Hence it has a positive sign if the intersection of the paraxial ray lies to the right of that of the marginal ray.

Coma, astigmatism, and *curvature of field* are oblique aberrations, that is, they do not appear in image points on the optical axis, so we shall defer their discussion until we have completed our lens design. We shall not attempt to correct our lens for these aberrations, but shall determine their magnitude and discuss the special equations for their computation.

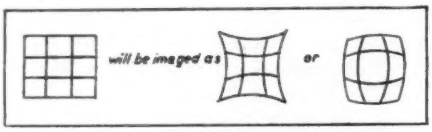


Fig. 10. Distortion of an image.

Distortion is not considered in astronomical objectives. It is the failure of a lens to reproduce a properly proportioned image (Figure 10.) We shall not compute it, but later give a definition for it in our discussion of the oblique aberrations.

8. **Correction for Chromatic Aberration.** Correction for chromatic aberration is, of course, achieved by using a two-component lens. The curvatures of the two components are so adjusted as to bring two specific wave lengths to the same intersection-point.

We wish, here, to derive approximate equations for the ratios of curvature of crown and flint necessary to achieve chromatic correction.

Recall that the focal length of a lens is given by

$1/F = (N-1)\,c$, where $c = 1/r_1 - 1/r_2$

Therefore, if the two wave lengths we wish to bring together are a and b, then

$1/f_a = (N_a-1)\,c$ and $1/f_b = (N_b-1)\,c$

for the crown lens, and

$1/f'_a = (N'_a-1)\,c'$ and $1/f'_b = (N'_b-1)\,c'$

for the flint lens.

Now, we also remember that the focal length, F, of a system of n thin lenses in contact is given by

$$\frac{1}{f_1}+\frac{1}{f_2}+\frac{1}{f_3}+\ .\ .\ .\ +\frac{1}{f_n}=\frac{1}{F}.$$

Therefore, the focal lengths for a and b through the double lens are

$$\frac{1}{F_a}=\frac{1}{f_a}+\frac{1}{f'_a}=(N_a-1)\,c+(N'_a-1)\,c'$$

and

$$\frac{1}{F_b}=\frac{1}{f_b}+\frac{1}{f'_b}=(N_b-1)\,c+(N'_b-1)\,c'.$$

The chromatic aberration, A, is

$1/F_a - 1/F_b$, or

$$A=(N_a-1)\,c+(N'_a-1)\,c'-(N_b-1)\,c-(N'_b-1)\,c'$$

or

$$A=(N_a-N_b)\,c+(N'_a-N'_b)\,c'.$$

Now, we desire the case where $A = 0$, or where

$$(N_a-N_b)\,c = -(N'_a-N'_b)\,c'.$$

Hence

$$\frac{c}{c'}=-\frac{N'_a-N'_b}{N_a-N_b}.$$

In glass catalogues, a function V is given, such that

$$V=\frac{N_d-1}{N_f-N_c},$$

where N_d is the refractive index for the sodium D line, wave length 5893 A. and N_f and N_c are, respectively, the indices for the hydrogen F and C lines, at wave lengths 4861 A. and 6563 A., respectively, which are the two wave lengths, in the green and the red, usually brought together for visual objectives. If it is desired to bring two other wave lengths together, a similar function for these wave lengths can be formed, if the indices are known.

We can write:

$$\frac{c}{c'}=-\frac{N'_a-N'_b}{N_a-N_b}\doteq-\frac{\dfrac{N'_a-N'_b}{N'_d-1}}{\dfrac{N_a-N_b}{N_d-1}}\doteq-\frac{\dfrac{1}{V'}}{\dfrac{1}{V}}=-\frac{V}{V'}.$$

The approximation symbol is used because (N_d-1) for the two glasses is not the same. However, in our sample computation we shall consider them equal.

EDITED BY EARLE B. BROWN

9. **Preliminary Computation.** We are now ready to design our lens. Our first problem is to decide its diameter, focal length, and so forth. This is to be an astronomical telescope objective, so it will be a large lens. Let us make it a 6-inch of focal ratio f/15. Therefore, we have

Diameter = 6 inches
Focal length = 90 inches.

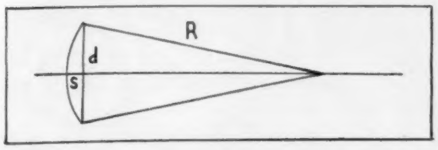


Fig. 11. Sagitta of an arc.

We select our glass and compute preliminary radii of curvature. Remembering that $1/F = (N-1)\,c$, we write $c = 1/F\,(N-1)$. Letting $N = 1.59$, we have $c = 1/53.1 = c + c'$.

This curvature is to be distributed between crown and flint according to

$$c/c' = -\,V/V'.$$

Let us take two common types of B. & L. glass, Light Barium Crown LBC-2 and Dense Flint DF-2. The glass catalogue gives us the following characteristics:

	LBC-2	DF-2
N_d	1.57250	1.61700
V	57.4	36.6
N_F	1.57953	1.62904
N_C	1.56956	1.61218

whence $V/V' = 1.56830$.
Therefore:

$c = -1.56830c'$; $c + c' = 1/53.1 = .01883$
$c' = -.01883/.56830 = -.03314$
$c = -1.56830(-.03314) = .05197$

Here, of course, c refers to the crown and c′ to the flint. If we call our radii, from front to rear, r_1, r_2, and r_3, and make the back surface of the flint plane, we have $1/r_4 = 0$; $1/r_3 - 1/r_4 = -.03314$; $r_3 = -30.1767'' = r_2$; $1/r_1 - 1/r_2 = .05197$; $1/r_1 = .01883$; $r_1 = 53.1''$

Next, we take into consideration the thickness of the lenses. Suppose the edge thickness of the crown to be ½″. Then the center thickness will be ½″ plus the sagittae of the two arcs, which is given by

$$s = d^2/2R$$

For r_1, $R = 53''$, $d = 3''$; $s = .10''$
For r_2, $R = 30''$, $d = 3''$; $s = .18''$

Hence, the center thickness of the crown will be $.50+.10+.18 = .78''$. And we shall choose .50″ for the center thickness of the flint, maintaining the usual 6 to 1 ratio for rigidity. *(Next installment in April)*

COMPUTING THE POSITION

(Continued from page 6)

where the (—) sign is shown. The arrows show how to proceed; the B value of 6109 is used twice. Certain rules must be followed in *naming K* (applying designations N and S) and in combining *K* and *L*; the result is called *K wiggle L*, and enables us to obtain the value for B of 6629, which is added to that of 6109 to obtain the A of 12738. This gives us, in turn, the value of h_c of 48° 13′.5, and a B of 17639 to subtract from the A of 30521. This subtraction gives us an A of 12882, corresponding to a Z of N131° 59′E, which, for practical purposes, is 132°. The intercept comes out 0′.2 away and is plotted from the *DR* position.

FORM FOR AGETON -- H.O. 211

G.H.A. 35° 26′.1	Body Obs. Moon L	h_o 48° 13′.3
DR Long. 65° 36′W	DR Lat. 42°08′N	Date 5-13-43
L.H.A. 329° 50′.1	Dec.(d) 9° 46′.8N	W 17-43-07
t 30° 09′.9E →	A 29885	
d 09° 46′.8N →	B 636	→ A 76975
	A 30521	→ B(−) 6109
K 11° 16′.5N		← A 70866
L 42° 08′.0N		B 6109
K~L 30° 51′.5 →		B 6629
h_c 48° 13′.5 ←	B(−) 17639	← A 12738
h_o 48° 13′.3	A 12882	
(o−c) 0′.2 away	Z N131° 59′E →	Z_n 132°.0

In the Ageton form above, two subtractions are indicated by (—) signs.

We have thus completed the use of the tables in working our sights. The only mathematics required are addition and subtraction. It is interesting to know, when we are painfully slow and unfamiliar with the process, that an experienced navigator can work a sight, using either of these tables, just about as fast as he can turn the pages and write down the figures.

Sauce for the Gander

FOR over two years now the author of "Do You Know" has been asking questions of others. What's sauce for the goose, you know . . . so now it's time for the readers to ask questions and watch this editor get into difficulties. Of course, he has one advantage, that he can select the questions he wants to answer; so he makes this agreement, that each month he will give, for the last question, the one he would have most difficulty in answering. Usually this one will be left unanswered. So send in your questions. This month's were received from Miss Caryl Annear, of Ocean Grove, N. J.

Q. As used in astronomy, what is the difference in meaning of the terms, *weight, mass, gravitation,* and *size?*

A. The terms are used in astronomy exactly as in physics. Mass may be defined as quantity of matter, and is ordinarily proportional to the number of protons and neutrons in a body. Mass is directly measured through inertia, or the resistance a body offers to a change in its motion. With different substances, or under different conditions of temperature and pressure, the same amount of mass may occupy different volumes, or sizes. Gravitation is the fact, or appearance of the fact, that bodies attract each other in amounts proportional to the product of their masses and inversely proportional to the square of the distance between them. Weight is the measure of this force upon a particular object in a particular place. Under similar conditions of gravitational field, weight is proportional to mass: hence, on the surface of the earth both mass and weight are measured in the same units, pounds or grams. The mass of an object remains the same, wherever it is moved; its weight varies with the gravitational field.

Q. What is the lithosphere of the earth?

L. J. LAFLEUR

The Starry Heavens in February

By Leland S. Copeland

The Twenty First-Magnitude Brilliants—Mystery of the Largest Sun—Three Choice Galactic Clusters

A nest among the stars.

THESE words, taken from the shortest book in the *Old Testament*, picturesquely describe our earth, Planet Three. Though they refer to Mount Seir, rocky fastness of the Edomites, they can be applied also to our entire globe. Compared with the vast dark lanes of the Milky Way and its billowy star clouds, both planet and mountain are insignificant.

As we look from our cosmic nest in February, we can see more than half of the 1st-magnitude stars. Early in the month, at 9 p.m. war time, Deneb Cygni is setting in the northwest, and late in February, shortly after 10 p.m., orange-hued Arcturus is rising in the northeast. Throughout the four weeks, nine others are conspicuous. White Canopus, tremendously bright, but very far away, is at its best near the meridian. It can be seen only by those who live south of latitude 37 degrees. In the eastern half of the sky sparkle Regulus, Pollux, and Procyon; near the meridian rules Sirius; and high in the western half gleam Capella, Betelgeuse, and Rigel, with Aldebaran, fiery eye of the Bull.

Every sky hunter should know the 20 stars of 1st magnitude. Achernar, end of the River, cannot be observed north of latitude 33 degrees, and still farther south are Rigil Kentaurus and Beta Centauri, which point to the Southern Cross, and Acrux, of the Cross.

There are only five more: bluish-white Spica of spring and early summer; ruddy Antares, and the white brilliants, Vega and Altair, all ornaments of summer and autumn; and Fomalhaut, white jewel of the dying year.

Three of the 20 leading stars, Canopus, Deneb, and Rigel, are so remote that the light by which we see them began its journey before Columbus discovered America.

On February evenings, as we turn from gazing at splendid Orion and at Sirius, apparently brightest star, we notice near the zenith the Charioteer or Wagoner, Auriga. This constellation represents Erichthonius, legendary king of Athens. A memorial to him can be found also on earth, the Erechtheum, a temple on the Acropolis.

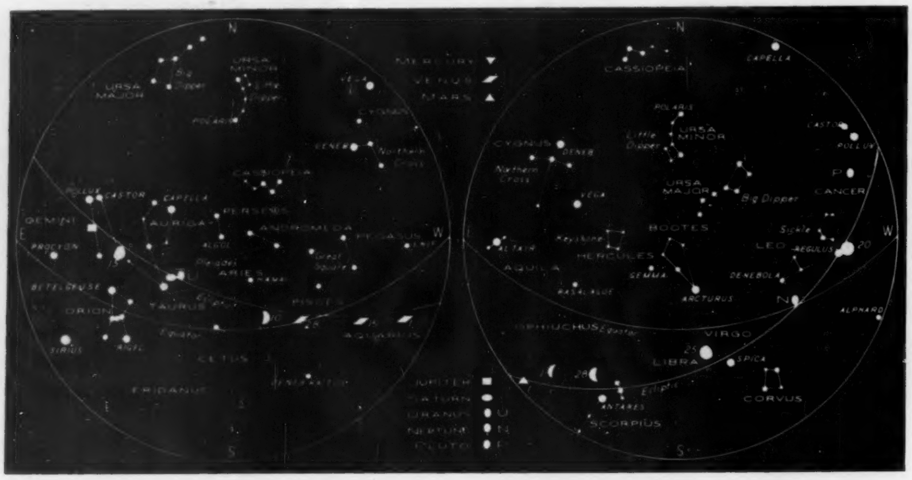
Pallas Athena herself was the foster mother of Erichthonius. To safeguard his infancy, she placed him in a chest and entrusted him to three young women. Two of the girls, over-curious, lifted the lid. When they thought they saw a snake inside, they leaped over the rim of the Acropolis and lost their lives.

"Erich," who was Vulcan's son, made a hobby of transportation problems. As a result he devised the four-horse chariot, an achievement remembered in the constellation of the Charioteer. Capella, chief jewel of Auriga, represents the kindly goat on whose milk Jupiter fed in Crete, after he had fled from his hungry father, Saturn.

Below Capella are three small stars forming the two Kids. The northernmost, ε, is a twin, two giants revolving around each other in 27 years. The larger contributes only a minute part of the light, and its substance is so tenuous that the smaller star shines right through it, so that it cannot completely eclipse its brighter companion. The big sun, which Dr. Otto Struve describes in The SKY for March, 1938, as an infrared vacuum, is the largest so far recognized in our Milky Way system, far vaster than Betelgeuse, Mira, or Antares.

Like Scorpius and Puppis, Auriga is noted for its beautiful clusters. M37 is one of the handsomest specimens in the sky. It is 20 minutes of arc in diameter and has 150 stars. M38, with 100 stars, is also beautiful. M36 is smaller than either, but interesting even through amateur telescopes.

THE MOON AND PLANETS IN THE EVENING AND MORNING SKIES



In mid-northern latitudes, the sky appears as at the right at 6:30 a.m. on the 7th of the month, and at 5:30 a.m. on the 23rd. At the left is the sky for 6:30 p.m. on the 7th and for 5:30 p.m. on the 23rd. The moon's position is marked for each five days by symbols which show roughly its phase. Each planet has a special symbol, and is located for the middle of the month, unless otherwise marked. The sun is not shown, although at times it may be above the indicated horizon. Only the brightest stars are included, and the more conspicuous constellations.

Mercury, a morning star, sparkles in Capricornus. It reaches greatest elongation west on February 18th, 26° 24′. This is not a favorable elongation for Northern Hemisphere observers.

Venus, evening star, shines in Aquarius. At the end of the month it will be near the vernal equinox.

Mars is in Sagittarius as a morning star.

Jupiter still moves backward in Gemini.

Saturn and *Uranus*, in Taurus, will resume eastward motion on February 6th and 8th, respectively. (A diagram of the path of Uranus appeared on the "Observer's Page" last month.)

Neptune is in retrograde motion in Virgo.

SEEIN' THINGS AT NIGHT

OF the 100 million galaxies that can be photographed through the 100-inch telescope, how many can be observed by unaided human eyes?

Without pondering you might answer, "Just one, the great spiral in Andromeda." That is a good beginning. M31, pictured on our back cover this month, is one of the farthest objects that the unassisted eye ever will see, but it is just a neighbor of our own galaxy, the greater part of a million light-years distant from us. On the other hand, this distance is so great that the galaxy's "spiral structure never has been seen with any telescope," says Dr. Edwin P. Hubble, "although it readily is photographed with small cameras."

After a moment's thought you would add, "Wait, there are three galaxies; we must include the two Magellanic Clouds, which I forgot because they are so far south."

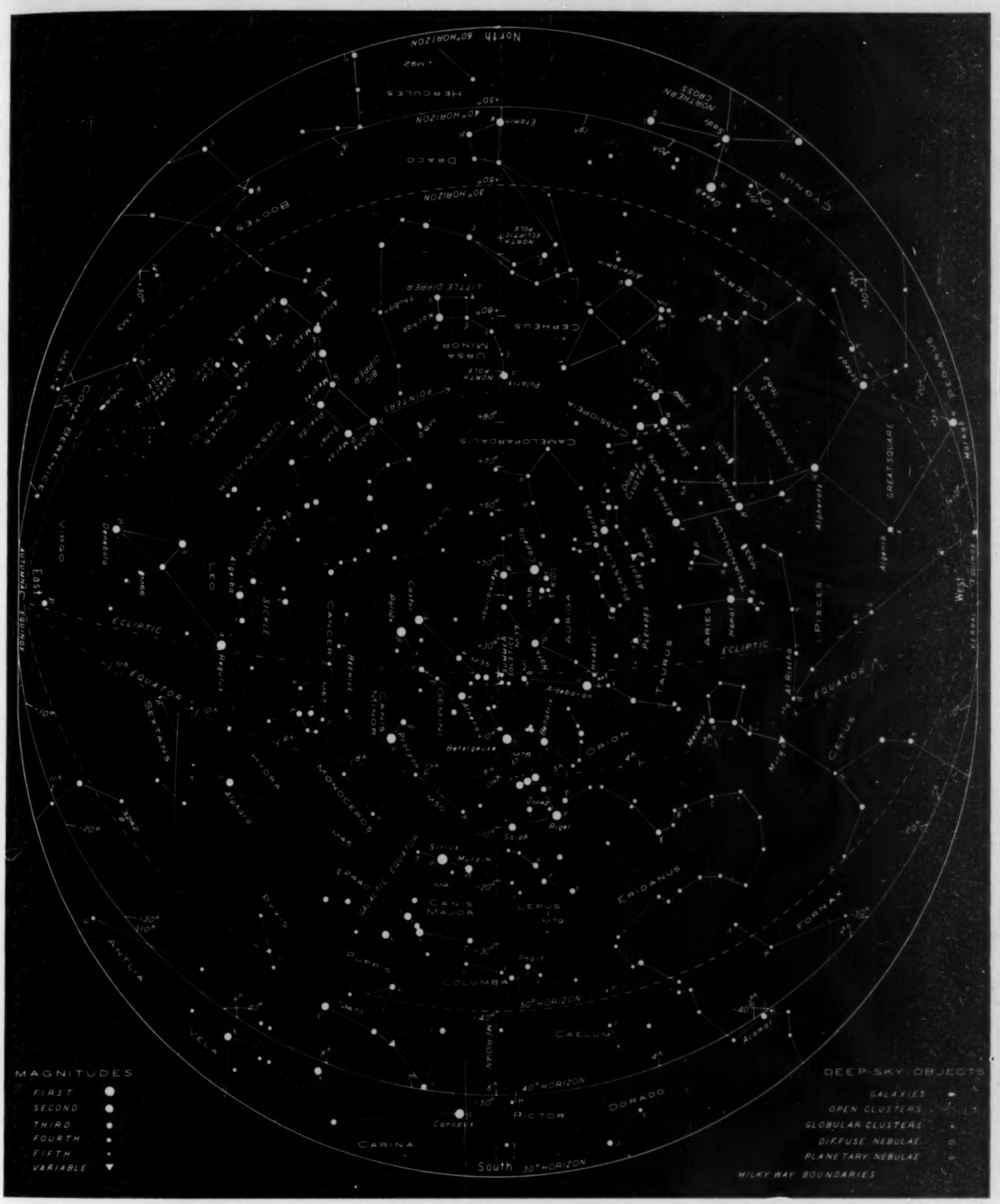
Good again—but the correct answer is five. One of these is so near that we easily overlook it—our own universe, the richest part of which we call the Milky Way.

But there is still another, M33 in Triangulum. This mature spiral, of which we have a full-on view, is an example of how our own universe would look from the outside, some astronomers believe.

If an Indian boy could see Alcor beside Mizar, his father was sure that the lad would be an expert hunter. In like manner, if you can glimpse M33 with the naked eye, even under the best conditions, you can be certain that you are good—as an amateur observer.

M31 was glimpsed as early as the 10th century A.D., but M33 probably remained unnoticed until it was revealed by telescopes. Without instrumental aid, this galaxy can be found by a far-sighted person when observing conditions are at their best.

Through the dark, clear air above Mt. Hamilton it can be perceived with little difficulty, according to Dr. Nicholas U. Mayall, of Lick Observatory. But if you are unable to spy it, find comfort in the words of Dr. Robert H. Baker, of the University of Illinois Observatory. Dr. Baker explains (can't you hear him chuckle?), "Except in remote places, such as the Moon and California, M33 is hardly a naked-eye object."



DEEP-SKY WONDERS

IN the night dome of February look for M33 in Triangulum between α of that constellation and β of Andromeda. The following attractions, including the great spiral in Andromeda, are waiting to entertain users of amateur telescopes:

Diffuse nebula: N.G.C. 1977, Orion, 5^h 30^m, $-5°$ 00′; fan of six stars in gauze.

Globulars: N.G.C. 3201, Vela, 10^h 15.3^m, $-46°$ 07′; M3, Canes Venatici, 13^h 39.7^m, $+28°$ 39′.

Clusters: M38, Auriga, 5^h 22^m, $+35°$ 45′; M36, Auriga, 5^h 29.5^m, $+34°$ 04′; M37, Auriga, 5^h 45.8^m, $+32°$ 31′.

Planetaries: N.G.C. 2438, Puppis, 7^h 39^m, $-14°$ 35′; M97 (Owl), Ursa Major, 11^h 12^m, $+55°$ 19′.

Galaxies: M31, Andromeda, 0^h 40^m, $+41°$ 00′, and its companions, M32 and N.G.C. 205; N.G.C. 2403, Camelopardalis, 7^h 32^m, $+65°$ 43′; N.G.C. 2683, Lynx, 8^h 49.6^m, $+33°$ 38′; N.G.C. 2903, Leo, 9^h 29.3^m, $+21°$ 44′.

THE STARS FOR FEBRUARY

as seen from latitudes 30° to 50° north, at 10 p.m. and 9 p.m. on the 7th and 23rd of the month, respectively. The 40° north horizon is a solid circle; the others are circles, too, but dashed in part. When facing north, hold "North" at the bottom, and similarly for other directions. This is a stereographic projection, in which the flattened appearance of the sky itself is closely reproduced, without distortion.

OBSERVER'S PAGE

By Jesse A. Fitzpatrick

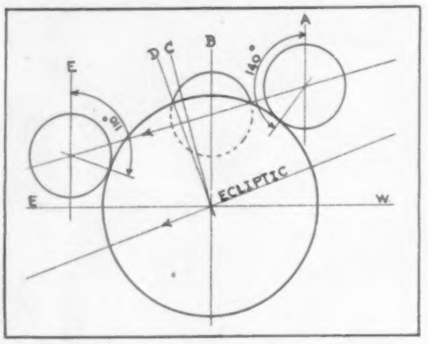
All times mentioned on the Observer's Page are Eastern war time.

The Partial Lunar Eclipse — February 19-20, 1943

A PARTIAL eclipse of the moon, visible throughout the United States, will take place during the late evening hours of February 19th and the early morning of the 20th, the hour depending on which part of the country the observer is in. In accordance with our custom, the times for the various circumstances will be given in Eastern war time. I have neglected the passage of the moon through the penumbra, feeling this phase of a partial eclipse to be of little interest to the amateur.

At the time of the eclipse the sun-earth distance, 91,954,200 miles, and the earth-moon distance, 248,526 miles, will give a diameter of 5,612 miles for the umbra or dark part of the shadow at the moon's distance from the earth. This will be increased to 5,650 in our computations (to allow for the effect of the earth's atmosphere in enlarging the shadow slightly) and it is equivalent to 1° 18′ 05″ of arc on the surface of the celestial sphere, based on the moon's diameter of 29′ 51″.

The center of the umbra, the large circle on the diagram, moves along the eclip-



tic, and its motion, as indicated by the arrow, is in a direction 20° 21′ 43″ south of due east. The path of the moon is 15° 8′ 17″ south of due east and its speed is approximately 12.5 times that of the umbra. It is interesting to compare the diagram of this eclipse with that of the eclipse in August, 1942, shown on the "Observer's Page" for that month. In that case the moon's speed was 15 times that of the umbra, due primarily to the earth-moon distance being nearly 20,000 miles less than for the February eclipse, so the moon moved correspondingly faster in its orbit.

The moon's first contact with the umbra at 0:03 a.m., February 20th, position A on the diagram, will be at 140° from the moon's north point. Since the position angle of the moon's axis at that time is 22°, the contact will be at 118° east of the north pole of the moon, which is a point on the edge marked by a line drawn from the moon's center through the crater Gassendi.

The conjunction in right ascension, B on the diagram, will occur at 1:19:55.3 a.m.

The middle of the eclipse, C on the diagram, will be at 1:38 a.m., at which moment the moon will be more deeply immersed in the umbra than at any other time, 0.767 of its diameter. Full moon, D on the diagram, will occur at 1:45 a.m.

The last contact, position E, at 2:13 a.m., will be 110° west of the moon's north point, or 132° west of the north pole, which is 6° south of the center of the crater Furnarius.

Prior to the eclipse, the 1st-magnitude star Regulus will be in conjunction with the moon. This will occur at 9:20 p.m. on the 19th, when the star will be north of the moon's edge by a distance equal to 42 per cent of the moon's diameter.

Variables *(Concluded)*

Some of the standard short-period pulsating variables, of which δ Cephei is the prototype, can also be observed by the novice. The time interval of δ Cephei is 5.37 days, and of η Aquilae, also in this class, 7.18 days. The color of stars in this group is generally white at maximum and yellow at minimum. These two stars vary from magnitude 3.6 to 4.3, a range sufficiently great to be easily detected.

Mira, o Ceti, is typical of the long-period pulsating stars, which are cool and red—always in the *M* spectral class, the degree varying from maximum to minimum. There is generally, but not always, a wide variation in the light intensity between these phases. Mira will be at its brightest about April 10th, but too near the sun for observation. The following list gives a few of the better-known stars in this class.

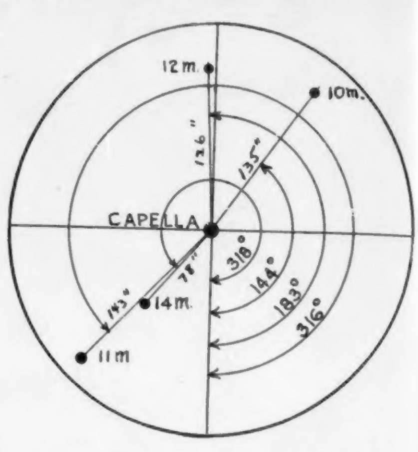
Name	Variation	Spectrum	Time Interval
Mira	2 to 10	*M7*	332 days
η Geminorum	3.3 to 4.2	*M0*	236 "
R Hydrae	3.5 to 10	*M7*	415 "
χ Cygni	4.2 to 14	*M7*	413 "
R Leonis	5.0 to 10	*M8*	310 "

PHASES OF THE MOON

New moon ....February 4, 7:29 p.m.
First quarter ......February 11, 8:40 p.m.
Full moon ....February 20, 1:45 a.m.
Last quarter ......February 27, 2:22 p.m.

MINIMA OF ALGOL

February 10, 4:30 a.m.; 13, 1:20 a.m.; 15, 10:09 p.m.; 18, 6:58 p.m.



CAPELLA'S COMPANIONS

THE 1st-magnitude star Capella and its interesting family of faint stars are in good position these February nights for the owners of small or medium-sized telescopes to test the limit of the light grasp of their instruments.

On the diagram I have shown the four companions with magnitude and position angle of each. Their magnitudes and distances from the primary are: 10, 135″; 11, 143″; 12, 126″; 14, 78″. The first two should be seen easily with 3-inch or 3½-inch telescopes, while a 4- or 4½-inch is required for the third; but a much larger glass, an 8- or 10-inch, will be needed for the 14th-magnitude star.

The 10th-magnitude star, sometimes known as H, belongs to spectral class *M*, red and cool; it has a 12th-magnitude companion whose distance is 1″.8. The seeing of this binary is an excellent proof of the perfection of a 4½-inch lens. When we remember that it requires 10,000 11th-magnitude stars, or 25,000 of the 12th magnitude, to equal the brightness of one 1st-magnitude star such as Aldebaran, we can appreciate the wonderful light-gathering abilities of our instruments.

Capella, magnitude 0.21, is of spectral class G0, similar to our sun, and it has a diameter about 10 times as great as the sun. Its distance is approximately 42 light-years.

The beginner will probably find it necessary to arrange to have Capella just outside his field of view, because of its brilliance. The companion stars are far enough away so this should not be necessary in the larger telescopes. I find that a magnification of 20 or 25 times the diameter of the objective is best suited for observations of this kind.

Should there be difficulty for the larger instruments in finding the 14th-magnitude star, an alternate is Alpha Leporis, which has a 13th-magnitude companion, distance, 91″, position angle, 186°. The magnitude of the primary, 2.69, will not cause such an interfering glare as does Capella. The constellation of Lepus is just south of Orion.

For smaller telescopes, an alternate test is the 11th-magnitude companion of Aldebaran, distance, 120″, position angle, 34°. Aldebaran's spectral class, *K*5, and its magnitude, 1.06, reduce its glare well below that of Capella.

OCCULTATIONS—FEBRUARY, 1943

Local station, lat. 40° 48′.6, long. 4^h 55.8^m west.

Date	*Mag.*	*Name*	*Immersion*	*P.**	*Emersion*	*P.**
Feb. 12	3.9	γ Tauri	9:45.8 p.m.	127°	10:43.6 p.m.	213°
13	6.4	70 Tauri	1:09.8 a.m.	93°	2:10.6 a.m.	257°
21	4.7	χ Leonis	2:43.5 a.m.	68°	3:39.2 a.m.	347°
23	6.1	BD −0° 2603	4:44.0 a.m.	160°	5:43.6 a.m.	255°

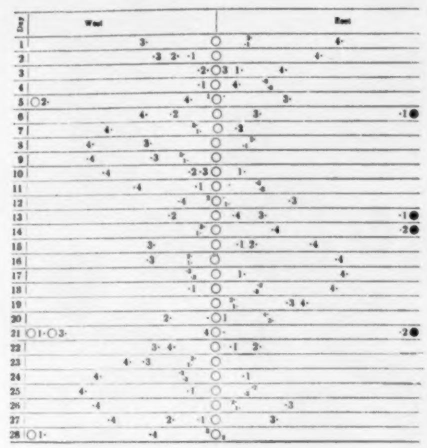
* P is the position angle of the point of contact on the moon's disk measured eastward from the north point.

THE list of double stars in the adjoining columns is the fifth in a series which will cover the entire sky, appearing bimonthly. The last list will be in the April issue.

JUPITER'S SATELLITES

THROUGHOUT the early part of the evening of February 20th, the four moons will be very close to Jupiter, and we may observe the unusual phenomenon of three of them disappearing within the space of 13 minutes. *III* will start to transit at 10:41 p.m., *II* will disappear behind the planet at 10:43, and *I* will begin its transit at 10:54, leaving *IV* alone on the east side. The latter will be the sole visible satellite until the reappearance of *I* at 1:10 a.m., followed by *III* at 2:06. *IV* will start to transit at 2:14 a.m.

Jupiter's four bright moons have the positions shown below at 12:45 a.m., E. W. T. The motion of each satellite is from the dot to the number designating it. Transits of satellites over Jupiter's disk are shown by open circles at the left, and eclipses and occultations by black disks at the right. From the American Ephemeris.



LIST OF DOUBLE STARS—R. A. 4h to 8h

	Star	*R. A.* h m	*Dec.* ° ′	*Photometric mag.* A+B	A	B	*Aitken mag.*	*Spectra* A	B	*Sep.* ″	*P.A* °
Auriga	(ω) 4	4 55.8	+37 49	4.99	......	(8.0)	5.0—8.0	A0	...	(5.8)	(355)
	14	5 12.1	+32 38	5.14	......	......	5.0—11.0	A2	...	(11.0)	(355)
	θ	5 56.3	+37 13	2.71	......	(7.5)	3.0—7.5	A0p	...	2.9	(325)
	41	6 07.3	+48 43	(5.6)	6.09	6.82	5.2—6.4	A0	A0	7.7	356
Canis Major	ε	6 56.7	−28 54	1.63	......	(8.0)	1.6—8.0	B1	....	7.5	160
	145	7 14.5	−23 13	(4.6)	4.82	6.82	5.0—7.0	K5	F0	27.0	58
Eridanus	55	4 41.2	− 8 53	(6.0)	6.67	6.75	6.6—6.8	F5	F5	9.0	317
Gemini	20	6 29.4	+17 49	6.72	7.24	7.78	6.0—6.9	F8	F8	19.5	211
	λ	7 15.2	+16 38	3.65	......	......	3.2—10.3	A2	....	(10)	(35)
	δ	7 17.1	+22 05	3.51	......	(8.2)	3.2—8.2	F0	K6	6.6	215
	α	7 31.4	+32 00	(1.6)	1.99	2.85	2.7—3.7	A0	....	4.5	200
	κ	7 41.4	+24 31	3.68	......	(8.5)	4.0—8.5	G5	....	6.9	236
Lepus	β	5 26.1	−20 48	2.96	......	......	3.0—11.0	G0	....	2.3	320
Lynx	12	6 41.8	+59 30	4.89	......	......	5.2—6.1	A2	....	1.7	104
	19	7 18.8	+55 23	(5.5)	5.61	(8.6)	5.3—6.6	B8	A0	14.8	315
Monoceros	8	6 21.1	+ 4 37	(4.3)	4.48	6.54	4.0—6.7	A5	A5	13.0	26
	β	6 26.4	− 7 00	(3.9)	4.64	4.73	5.0—5.5	B2e	B2e	7.5	132
	S	6 38.2	+ 9 57	4.68	......	......	6.0—8.8	Oe5	....	3.0	212
Orion	β	5 12.1	− 8 15	0.34	......	......	1.0—8.0	B8p	....	9.5	201
	λ	5 32.4	+ 9 54	3.66	......	......	4.0—6.0	Oe5	....	4.3	44
	θ1	5 32.8	− 5 25	5.36	......	......	7.0—8.0	Oe5	....	8.7	32*
	θ2	5 32.9	− 5 27	5.17	......	......	4.8—6.1	B1	....	52.0	92
	ι	5 33.0	− 5 56	2.87	......	......	3.2—7.3	Oe5	....	11.4	141
	ζ	5 38.2	− 1 58	2.05	......	......	2.0—5.7	B0	....	2.6	.158
Puppis	κ	7 36.8	−26 41	(3.8)	4.50	4.62	5.0—5.0	B8	B3	9.6	318
Taurus	χ	4 19.5	+25 31	5.38	......	......	5.7—7.8	B9	....	20.0	25
	118	5 26.2	+25 7	5.86	......	......	5.8—6.6	A0	....	5.2	206

* The A-B pair in the Trapezium. AC are magnitudes 7.0 and 4.7, sep. 13.0, P.A. 131°. AD are magnitudes 7.0 and 6.3, sep. 21.0, P.A. 95°.

The columns are: star designation; right ascension, declination (1950); photometric magnitudes; "Aitken" visual magnitudes; spectral classes; separation; position angle.

A and *B* are the brighter (primary) star and fainter star, respectively. Where available, the photometric magnitudes are given to two places; magnitudes in parentheses are estimated or uncertain. "Aitken" magnitudes are from visual observations and often differ greatly from the photometric figures, therefore the former are useful chiefly to indicate the relative magnitude difference between the components.

The data for this table is compiled from the Boss *General Catalogue;* Aitken's *Double Star Catalogue;* and Innes' *Southern Double Stars.*

PLANETARIUM NOTES

Sky and Telescope is official bulletin of the Hayden Planetarium in New York City and of the Buhl Planetarium in Pittsburgh, Pa.

★ **THE BUHL PLANETARIUM** presents in *February*, THE ROMANCE OF ECLIPSES.

The eclipse of the moon, taking place this month, makes timely this sky show which traces the romantic story of all kinds of eclipses. Few celestial sights are more arresting than the slow darkening and reddening of the moon, as it slides into the shadow of our own earth. And none is more awe-inspiring than a total eclipse of the sun, with the stars shining forth by day, and the delicate beauty of the solar corona flashing all at once into view. But other varieties of eclipses occur at times, each interesting in its own way. In this production we see them all, and the reason for them all, the mechanism behind these thrilling blackouts of the sky—the whole gamut of eclipses in one short hour.

★ **THE HAYDEN PLANETARIUM** presents in *February*, OUR PLANETARY NEIGHBORS. (See page 7.)

In *March*, STARS IN SONG AND STORY. Down through the years artists, poets, writers, musicians have drawn on the vast resources of the heavens for inspiration for their art. In this month's Planetarium show, we shall take from their work the most interesting and curious references and connect them to the sky itself. The famous errors of song and story, too, will be discussed.

★ SCHEDULE BUHL PLANETARIUM

Mondays through Saturdays (except Tuesdays)......3 and 8:30 p.m.
Sundays and Holidays.........................3, 4, and 8:30 p.m.
(Building closed Tuesdays)

★ STAFF—*Director*, Arthur L. Draper; *Lecturer*, Nicholas E. Wagman; *Manager*, Frank S. McGary; *Public Relations*, John J. Grove; *Chief Instructor of Navigation*, Fitz-Hugh Marshall, Jr.; *Instructor, School of Navigation*, Edwin Ebbighausen.

★ SCHEDULE HAYDEN PLANETARIUM

Mondays through Fridays...................2, 3:30, and 8:30 p.m.
Saturdays ....11 a.m., 2, 3, 4, 5, and 8:30 p.m
Sundays and Holidays...................2, 3, 4, 5, and 8:30 p.m.

★ STAFF—*Honorary Curator*, Clyde Fisher; *Curator*, William H. Barton, Jr.; *Assistant Curators*, Marian Lockwood, Robert R. Coles (on leave in Army Air Corps); *Scientific Assistant*, Fred Raiser; *Lecturers*, John Ball, Jr., Charles H. Coles, Charles O. Roth, Jr.